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THE ELECTRICAL PRECIPITATION OF SUSPENDED MATTER IN GASES.[1]

BY

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THE purpose of the present investigation is to study the electrical properties of gases containing solid and liquid matter in suspension (especially smoke from soft coal), and to ascertain the manner by means of which an electrostatic or an electromagnetic field will cause a separation of the suspended solid and liquid matter from a gas. As the most effective electrical process for removing the suspended matter from gases necessitates the presence of the electrical wind or of the corona form of discharge, a brief description of these two forms of discharge and their probable action upon solid and liquid particles suspended in the gas will be given. The following is the outline of the paper:

1. A review of work upon electrical precipitation.
2. Experimental apparatus.
3. The various types of electrical precipitation.
4. Aggregation. (*a*) The attraction between charged particles. (*b*) The Bjerknes effect.
5. Precipitation and ionization. (*a*) The electrification of

[1] Communicated by the author.

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dust and sprays. (*b*) Smoke patterns. (*c*) The effect of ionization on the sparking potential in flue gases.

6. The electrical wind and its action upon suspended particles. (*a*) The Cottrell method of precipitation.

7. The corona discharge and its action on particles suspended in a gas. (*a*) Application to the precipitation of cement dust.

8. Precipitation of coal smoke.

9. Summary.

(1) ELECTRICAL PRECIPITATION.

The precipitation of suspended matter from gases by means of electrical discharges was suggested by Hohlfeld [1] in 1824 and by Guitard [2] in 1850. Lodge and Clark [3] and Lodge [4] were the first investigators to go into the problem extensively. Lodge states that the discharge from points kept charged to a high potential by means of an electrostatic machine produced a clearance of the suspended matter in the neighborhood of the points. This clearance seemed to be independent of the nature of the suspended material and of the sign of electrification of the point. Walker [5] patented the above "process for separating and collecting particles of metals or metallic compounds, applicable for condensing fumes from smelting furnaces and for other purposes." According to Walker's arrangement, one electrode of the electrostatic machine was earthed, while the other was connected to an electrode covered with metallic points, against which the fumes made contact. This is the "active" electrode.

Apparatus of the above type was installed in the Dee Bank Lead Works, but on account of the unreliability of the source of electricity—Wimshurst electrostatic machines—the method was apparently a failure. Thwaite [6] took out a patent in 1899 in which a barbed wire is used as the active electrode. In the description this is mentioned as being positively charged.

It is to F. G. Cottrell [7] and his coworkers that we owe the

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[1] Kastner, Archiv. Naturl., 2, p. 205, 1824.

[2] *Mechanics' Magazine*, Nov., 1850.

[3] *Nature*, 28, p. 297, 1883.

[4] *J. Soc. Chem. Ind.*, 5, p. 572, 1886.

[5] English patent 11,120, Aug. 9, 1884; U. S. patent 342,548, May 25, 1886.

[6] U. S. patent 617,618, Jan. 10, 1899.

[7] U. S. patents 895,729, Aug. 11, 1908; 945,917, Jan. 11, 1910.

recent commercial development of electrical precipitation. In his 1908 patent he claims the following conditions to be favorable for successful operation: First, the current should be unidirectional, or, at least, the time occupied by its reversal should be large compared with the time of deposition of the individual suspended particles; second, the particles should be charged at or near the electrode about which the brush discharge appears (the "active" electrode); third, the particles should be deposited on a surface from which there is practically no brush or wind discharge (earthed electrode); fourth, the suspended particles in the gas should be subjected to as uniform treatment as possible. High voltage alternating current was made unidirectional by the use of a synchronously-driven rotating commutator. In order to make the brush or glow discharge as great as possible, the active electrode was wound with asbestos threads, strips of mica, etc. The surface of the asbestos is usually moist enough to act as a conductor so that the exposed fibres give point discharges into the gas. Such electrodes Cottrell calls "pubescent." The patent includes claims to the maintenance of the insulation of the pubescent electrodes by means of currents of clean gas and by heating. Howard [8] took out a patent on the use of horizontal plate electrodes for precipitating fumes. Nothing is stated concerning the electrical conditions necessary.

In a patent taken out by Dion [9] the action of the electrical current is that of aggregating the fume particles and then allowing them to settle. It is stated that under the same conditions metallic particles of different kinds are precipitated to a different degree, and this fact is stated as affording a means of separating the various fume materials. Metallic plate electrodes are described, the electrodes being of a composition determined by the kind of fumes to be precipitated. Direct current of apparently low voltage is used to charge the electrodes. A description of the plants that have been planned more or less along the lines indicated in the Cottrell patent will be given in the latter part of this paper.

(2) EXPERIMENTAL APPARATUS.

For the purpose of studying the smoke produced in the burning of soft coal, a small building about 12 by 15 feet was

[8] U. S. patent 896,111, Aug. 18, 1908.
[9] U. S. patent 925,626, June 22, 1909.

built. This building included a small furnace and an underground pipe, by means of which the smoke could be conveyed

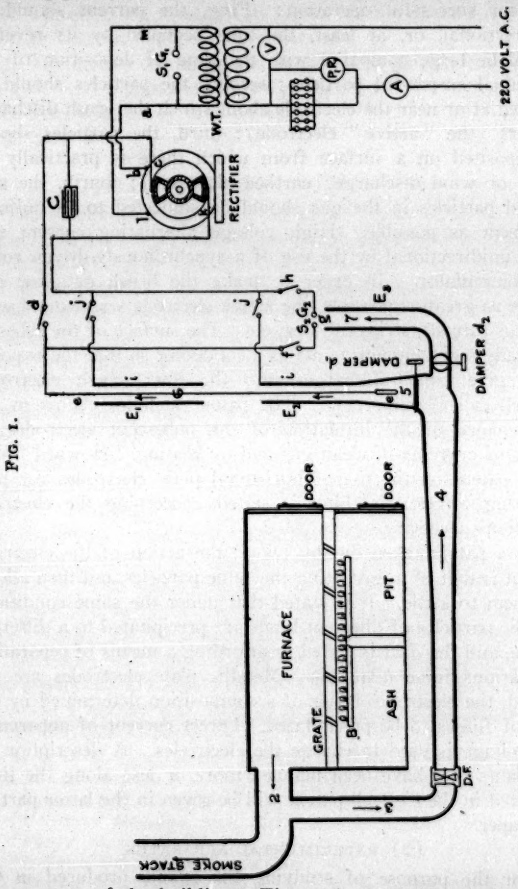

FIG. 1.

to any part of the building. Fig. 1 shows the furnace, 60 cm. high, 60 cm. wide, and 100 cm. long. Below the furnace is an

ash pit. *B* is a gas (natural gas) burner used for starting the fire. The inside of the furnace is lined with refractory brick, while the outside is covered with ordinary brick. On account of its construction the furnace proved to be a most efficient smoke producer.

D.F. is a small fan run by an alternating-current motor. When the fan is running, smoke is carried in the paths 2 3 4 5 6 or 2 3 4 7, according as the damper d_1 is open and d_2 is closed or d_1 closed and d_2 open. The draft in a 3-inch pipe could be varied from zero to 0.5 inch of water.

The electrical apparatus used in these experiments has been mostly of the sort to give the various kinds of high-tension discharges. This has included a Wimshurst electrostatic machine, a pneumatic influence machine, a Fessenden wireless induction coil, a Westinghouse instrument transformer, small Blitzen and Marconi transformers, and a high voltage rectifier. The Wimshurst machine, the Fessenden coil, and the Westinghouse transformer were very kindly loaned for the work by Dr. Bishop, of the Physics Department of the University.

The pneumatic influence machine was obtained through Eimer & Amend, of New York. It had cylinders 15 inches in diameter, enclosed in a case 10 inches thick. These machines are made to work under a pressure of about 50 pounds per square inch. The plates are made of a nonoxidizable material, so that the presence of discharge does not result in a breaking down of the insulation. The machine used is stated as giving an 11-inch spark at a pressure of 30 pounds. The Westinghouse transformer is rated to give 60,000 volts, and withstands as much as 80,000 volts. Hague and Olesen [10] give the ratio of transformation as 237. Two Westinghouse potential induction regulators accompanied the transformer so that the voltage on the primary could be varied between 0 and 350. The Blitzen transformer was a small one, weighing about 40 pounds, operating directly on the 110 alternating-current terminals and giving about 15,000 volts.

The rectifier was purchased from the Balaklala Consolidated Copper Smelting Company, of Coram, Calif. It was built for strength, and stood on a heavy cast-iron base. It was started

[10] Dissertation, "Determination of Electrostatic Fields," University of Pittsburgh, 1911.

by a direct-current motor, and when in synchronism was run by a 220 three-phase alternating-current motor working on the shaft of the rectifier itself. Through the generosity of Dr. Cottrell we have been loaned one of his rectifiers.

In the figure *W.T.* is the Westinghouse transformer; S_1 G_1, a protective spark gap; *A*, an alternating-current ammeter; V, a voltmeter; *L*, a bank of lamp resistance; P_1 R_1, a potential regulator that could be connected in the primary circuit, *L* then being cut out; *C* is a condenser, which, however, is seldom used. By the proper switch connections the high-tension current can be made to flow through either of the circuits *a b c d e i j l m* or *a b c d f g h l m*. The former circuit contains an active wire electrode, *e*, suspended in the middle of pipes E_1 and E_2. The part E_1 could be insulated or earthed. One use to which E_1 is applied is that of obtaining a precipitation of particles that are not thrown down in E_2. The pipe E_3 is used to make spark gap measurements.

The spark gap S_2 G_2 can be varied in length and can also be subjected to flue gases of different temperatures, velocities, or smoke content, depending on the condition of the furnace, the speed of the fan *D.F.*, and the pipe dimensions.

A few experiments were made with S_2 G_2 placed in the smokestack, but the arrangement is not represented in the figure.

(3) THE VARIOUS TYPES OF ELECTRICAL PRECIPITATION.

Suspended solid and liquid particles in gases may be acted upon in various ways by an electric field so that some or all of the particles are drawn from the gas to the electrodes. (1) If the particles are conducting, the effect of the electric field is to polarize the particles, inducing a positive charge on one side and a negative charge on the other side. This action of the field probably plays an important rôle in producing aggregates of fine particles that are close to each other. (2) If the suspended particles are non-conductors their dielectric constant will be greater than that of the gas, and in an electric field that is not uniform the particles will move into the more intense part of the field. (3) Gaseous ions may be present in the gas, and some of these will combine with the suspended particles. Such charged particles are the large ions, and these move very slowly

in the weaker fields. Large ions are always gaining and losing charges, and this process may aid in aggregating together the smaller particles. (4) The above processes, by means of which suspended particles can be removed from a gas, apply only to cases where the gases move very slowly between the electrodes. When there is intense ionization and an intense electric field, streams of ions will be created between the electrodes. Under these conditions the streams of ions carry the suspended particles in the gas with them to the electrodes, to which they give up their charge. Streams of ions are produced in the various point, brush, and corona discharges. The ions in these cases are probably produced by collision or secondary ionization in the regions where the electric field is the most intense.

The relative importance of the above effects in removing suspended particles from a gas is quite different. Polarization of the particles probably causes the formation of comparatively large aggregates, and these can then be swept out of the gas by the streams of ions flowing through it.

Particles possessing any considerable size possess such a small mobility when ionized that they are given a very small velocity by the electric field. On the other hand, the driving force due to ionic streams increases as the mobility of the heavy particles decreases, so that the effect of these streams becomes the predominating one for the larger particles.

(4) PRECIPITATION BY AGGREGATION.

The precipitation due to the formation of an electrical wind or of a corona discharge is accompanied by more or less aggregation and a settling of the larger suspended particles. The cause of this aggregation is not well known, but there is no doubt that the sound waves radiating from the discharge have some effect. The sound waves act in a similar manner to the phenomena in the ordinary Kundt's tube, used in measuring the wave length of sound waves.

Some writers claim that electromagnetic waves produce an aggregating effect upon the small water drops in fogs and mists for comparatively long distances from the source of the waves. M. Dibos [11] claims that he has succeeded in clearing fog for

[11] Soc. Ing. Civ. France, Bull. 60, p. 451, 1907.

distances of 50 or 60 yards by means of high potential discharges from points (140,000 volts). Lodge is said to have made clearances for similar distances by means of electromagnetic waves.

It is generally accepted at present that, at atmospheric pressure, ions are not single charged gaseous molecules, but that they consist of many molecules combined with each other in the form of aggregates. The small mobility and coefficient of diffusion of the ions indicate that their mass is much greater than that of the average molecule. As an ion moves through the gas it attracts neutral molecules to it, especially during collisions, and there results an increase in the mean collision frequency of the ion and consequently a diminution in its mean free path. There is, therefore, a constant change in the size of the ionic aggregate as it moves through the gas.

Not only is there an attraction between oppositely charged particles and between charged and uncharged particles, but, under certain conditions dependent upon the relative dimensions of the particles, there may be an attraction[12] when they are both charged positively or negatively.

It is probable that the electrical forces play quite an important rôle in determining the size of the particles in smoke and fumes. Presumably the chemical reactions, such as those taking place in combustion, are between the individual molecules. If this is true, the carbon of smoke must exist for a time in the atomic condition. Whether chemical reactions directly produce ions or not, it is true that, under the usual conditions, combustion and all chemical reactions taking place at a high temperature are accompanied by intense ionization. During a considerable part of the time the suspended solid and liquid particles are subjected to the action of intense electrical fields. They may become charged by direct union with ions or by induction, and these electrical forces probably determine, in part at least, the size of the resultant aggregates.

The action of electromagnetic waves upon suspended particles in gases may be of the same nature as the action on the Branly and other coherers made of carbon or metallic filings.

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[12] See various sections in Lord Rayleigh's and Lord Kelvin's Collected Papers; Russell, *Phys. Soc. London*, 24, p. 22, 1911; Burton and Weigand, *Phil. Mag.*, 23, p. 148, 1912.

Sound waves cause the particles of smoke or fume to be set into motion. Moving particles [13] that are near each other experience an attraction or a repulsion, depending upon their relative motion. An effect of this kind is shown in the Kundt's tube, where particles of lycopodium or any kind of dust are caused to collect together when stationary waves are produced in the tubes. It has been suggested by Dr. Speyers that a scheme might be devised to clean gases of suspended particles by producing a stationary wave in the gas and providing outlets for the gas between the regions where the particles were caused to collect by the Bjerknes effect.

What rôle electromagnetic and sound waves and the polarizing action of an electrical field play in the electrical precipitation of smoke is not known, but these effects are probably subsidiary.

When a synchronously-driven rotating commutator is placed in the high-tension circuit to produce a unidirectional current, four spark gaps, each two or three millimetres in length, are introduced. It results from this condition that in some respects the active electrodes act as antennæ, emitting electromagnetic waves. Whether these waves aid in electrical precipitation is not at present known. Certainly this is true, however. The introduction of these spark gaps results in increasing the positive brush discharge about the active electrode very greatly.

(5) PRECIPITATION AND IONIZATION.

(*a*) *Electrification of Dust and Sprays.*

In order to test whether fine particles of carbon and sprays from various liquids could be electrified or not, the dust and spray was caused to pass through a region where the electrical field produces intense ionization. The blower or spray nozzle, by means of which the fine particles were blown into the air, had its opening connected to an electrode of an electrostatic machine with spark gaps set so that it would give 45,000 volts. The other electrode was earthed and contained openings through which the spray could be blown upon an electrode, connected to an electroscope. The various kinds of dust and spray were found to be electrified with varying degrees of ease, the numbers representing approximately the relative volume of sprays re-

[13] Bjerknes, "Hydrodynamische Fernkräfte."

quired in each case to charge an electroscope to the same potential.

Substance.	Comparative negative.	Electrification positive.
Calcium oxide dust	1	2
Carbon dust	1	1
Ethyl alcohol	1	.8
Ether	1	.7
Toluol	1	Little effect.

The table shows that some substances, such as toluol, can be given a negative charge, but are difficult to charge positively. Experiments of this kind should throw considerable light upon the mechanism of electrical precipitation. Sprays of non-conducting substances can be electrified when they are passed through regions where electrical discharges are taking place. No means were taken to produce spray particles of the same size except that the same atomizer and air pressure was used for each liquid.

(*b*) *Smoke Deposit Patterns.*

A considerable number of investigators have studied the patterns or dust figures formed by flowers of sulphur, red lead, lycopodium powder, etc. The form of the patterns may be very complex and their explanation has at present only been partially given.

In the present investigation numerous deposits have been made of kerosene and soft coal smoke on paper, on one side of which a high-tension electrode was placed normal to the paper, the smoke of the opposite side of the paper being attracted to the paper and caused to be deposited on it by the electric field. The forms of these deposits were in general found to consist of concentric regions of alternating heavy and light deposit: (*a*) the inner nucleus (.4 or .5 cm. in diameter) consisted of a region of heavy deposit; (*b*) a clear circular region (1.5 cm. inside diameter) surrounded the nucleus, and this may be called the first clear ring; (*c*) a ring-shaped deposit, consisting of comparatively fine particles, followed, the thickness being about .8 cm. (first ring deposit). For strong fields (40 or 60 kilovolts) a second clear ring and a second ring deposit surrounded the first ring deposit.

It was hoped that relations could be obtained between the form of the smoke deposit patterns and some of the properties of the electric field and the discharge from the electrode. As yet no relations of this kind have been obtained, although the deposit pattern is somewhat different for positive, negative, and alternating potential electrodes.

This action of the electric field has been utilized in an instrument designed for continuously recording the amount of suspended matter (such as smoke and fumes) in gases.

(*c*) *The Spark Potential in Gases from Burning Coal.*

The most important factor that determines the sparking potential in flue gases is the amount of ionization. Experiments [14] with pure gases show that the minimum sparking potential depends upon the mass of gas between the electrodes and changes but little between 20° C. and 600° C. when the gas pressure is kept constant. When the source of the ionization is due to combustion, ionization will generally increase with rise in temperature.

The source of potential used for obtaining the effect of rise in temperature and of the presence of smoke consisted of the Westinghouse transformer connected to the 220-volt, 60-cycle terminals, with a sufficient number of incandescent lamps in the primary circuit to reduce the current to about one ampere. The effective voltage across the terminals of the secondary circuit was about 20,000. The spark in air under room conditions was oscillatory and was about 28 mm. in length for the kind of electrode used (electrodes 3 mm. in diameter with conically-shaped ends).

In order to compare the spark gap lengths in air and in the furnace gases, two spark gaps were connected in the high voltage circuit in parallel, one in air (A) and one in the gases S_2 G_2 drawn from the furnace. Only S_2 G_2 is shown in Fig. 1. The length of the gap S_2 G_2 was made as great as possible without causing sparking in A. This length corresponds to the length of gap in the flue gases under the given conditions for a sparking potential of 20,000 effective volts.

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[14] Earhart, *Phy. Rev.*, 30, p. 293, 1909; 31, p. 652, 1910

Experiment 1.—Gap A, 26 mm. in length. Draft in pipe above which is located gap S_2 G_2, 0.2 inch water.

Temperature of flue gas. No smoke.	Length of gap S_2 G_2
163° C.	28 mm. partly oscillatory
175° C.	30.5 mm. partly oscillatory
190° C.	30.5 mm. partly oscillatory
200° C.	33 mm. brush discharge
235° C.	34 mm. brush discharge
248° C.	40 mm. brush discharge
250° C.	50 mm. brush discharge

As the temperature increases, and therefore the intensity of the ionization in the gas, the bright oscillatory streamers of the spark decrease in number and the discharge is gradually converted into a brush discharge from each electrode. The brush consists of a violet fan-shaped discharge, and at the higher temperatures this brush discharge lowers the potential sufficiently to prevent any discharge taking place in *A*, even though the gap S_2 G_2 is made very long.

Experiment 2.—Conditions analogous to those in the above experiment, with the exception that the draft is only about 0.1 inch of water. The density of smoke is usually given in terms of the Ringelmann Scale.

Temperature of flue gas.	Length of gap S_2 G_2.	Smoke conditions.
Room conditions,	28 mm.	....
Flue gas 35° C.	35 mm.	....
Flue gas 60° C.	35 mm.	....
Flue gas 90° C.	37 mm.	....
Flue gas 95° C.	45 mm.	....
Flue gas 95° C.	30 mm.	Dense smoke

The effect of smoke is to change the brush discharge into an oscillatory one, like that occurring under ordinary room conditions, although the temperature is not materially lowered. The effect is due to the smoke particles greatly reducing the amount of ionization in the flue gases, the rate of recombination of the ions being greatly increased.

Experiment 3.—At ordinary temperatures the effect of draft is to blow out the spark, and in order to maintain sparking the length of gap must be decreased. As the ionization in the gas

increases and as the brush discharge becomes more prominent the effect of change of draft becomes less, as is shown by the following measurements, the gap S_2 G_2 being kept as long as possible without sparking taking place in A.

Draft.	Temperature.	Length of gap S_2 G_2.
0	25° C.	21 mm.
0.1 in. water	35° C.	18.5 mm
0.2 in. water	35° C.	17.5 mm.
0.6 in. water	35° C.	16.5 mm
0.05 in. water	135° C.	19 mm.
0.25 in. water	135° C.	18 mm.
0.4 in. water	130° C.	17 mm.
0.05 in. water	115° C.	19.5 mm.
0.2 in. water	160° C.	18.5 mm.
0.5 in. water	180° C.	20 mm. Brush discharge

Similar changes of draft have very little effect upon the length of the gaps when there is smoke at a temperature of about 200° C.

The above effect of smoke and suspended particles upon the ionization in gases is being utilized as a means of working a monitor that will indicate the presence of suspended matter in gases.

The point discharge between electrodes in smoke, placed as close together as possible without sparking, is interesting, in that it shows the effect of smoke upon the character of the discharge. The following is a short description of the effect produced when the current is rectified:

(*a*) The appearance of the electrical discharge in hot gases or in smoke is the same when the electrodes are connected to a transformer through a rectifier as when connected to an electrostatic machine.

(*b*) In hot gases the discharge from the positive electrode consists of a violet brush of streamers about a centimetre or more in length. The negative brush is much shorter and is more stationary in character. Draft seems to have little effect in changing the position of these brushes. The violet brush discharge produced on electrodes connected directly to the transformer is greatly affected by draft.

(*c*) In smoke the positive and negative brushes are blue in color. Smoke is rapidly deposited on the positive electrode

to a thickness of 6 or 8 mm., the end of the deposit being blunt. The positive brush distributes itself over the deposit of soot. The deposit on the negative electrode is much less, about a millimetre of the end remaining free. The negative brush does not spread out like the positive brush.

(*d*) At the base of the negative brush bright, scintillating points appear. These are probably due to small particles of carbon being heated to incandescence. It may be that it is in this way the end of the electrode is kept free of smoke. Nothing of this kind takes place on the positive electrode.

(6) THE ELECTRICAL WIND.

It has been shown by Townsend that when an ion is given a sufficient velocity by an electrical field it will ionize molecules on collision with them. For a given pressure of a gas there will be a certain minimum value of the electric field required to give the ions sufficient velocity to produce other ions by collision. This phenomenon is known as secondary ionization and is generally considered to be the process by means of which the ionization of sparks, corona discharges, etc., is produced. In the region of a point charged to a high potential the electric field will be very intense. If this field is sufficiently intense it will cause the small number of ions (initially in the gas before the field was produced) present to move with sufficient velocity to produce secondary ionization. Ions having a sign of charge opposite to that of the point will move to the point and give up their charge. Ions having the same sign of charge as the point will be repelled by it, and these will form ionic streams flowing from the point.

The term ion is applied to any small particle ranging in size from that of ordinary dust or smoke particles, visible to the eye, to particles of molecular magnitude. The force acting upon an ion of charge e in an electric field of strength E will be Ee and the velocity of the ion will be kE, k being the velocity of the ion for a potential gradient of 1 volt per cm. Among the various theoretical values given to k is the formula of Langevin[15]:

$$k = \frac{eL}{MV}$$

M is the mass of the ion, L the mean free path of the ion, and V is the mean velocity of the ion due to its thermal agitation.

[15] *Ann. de Chim. et Phys.*, p. 289, 1903.

The value of k, the mobility of the ion, or the velocity with which it moves in a field of unit intensity (a potential gradient of 1 volt per cm.) ranges from 1.5 cm. per second for ions of molecular size to 0.003 cm. per second for the larger ions existing in the free air. The mobility of charged dust and smoke particles is probably much less than 0.003 cm. per second. In the electrical precipitation of dust and smoke the potential gradient is of the order of 5,000 volts per cm. For ions with a value of $K = 0.003$, this value of the electric field would give a velocity of one or two centimetres per second. This velocity is too small to cause ions of this kind to be precipitated. As ordinary ionized smoke and dust particles have a smaller value of k than the above, it is seen that this action of the electric field will not be efficient in producing precipitation, it being assumed that the charge on the smoke particles is small.

One action of the ionic streams on dust and smoke particles is the same as that of the action of a stream of cathode rays used to turn wheels having thin vanes, the wheels being properly placed in the discharge tube. An action of this kind will increase with an increase in the size of the particle bombarded.

In the above discussion it has been assumed that the value of e is the same for the small ions as for the large ions. While this is not rigidly true, yet in ordinary cases of ionization e probably never rises to any very considerable value, so that in the formula

$$k = \frac{eL}{MV}$$

the only quantity that shows any great variation is M.

As the value of M increases, the size of the ion will increase. Suppose the ion consists of a dust particle that is large enough to be seen. Place such a particle in the path of a stream of rapidly-moving ions produced by a point discharge. It will be subjected to a very large number of collisions by these ions, the number being much greater in the case of a large particle than it would be if the particle was of molecular dimensions. These collisions are all with ions moving in the same direction, hence the particle is given a large momentum in the same direction as that of the ionic streams.

In the region of a pointed electrode charged to a high potential

we have seen that the electric field can produce an intense ionization due to ionic collisions with molecules of the gas. This secondary ionization results in the formation of a large number of small ions, for which the value of k is large. Ions of molecular size and of the same sign of charge as the point will be repelled from the point with a velocity of thousands of centimetres per second and in great numbers. These ionic currents will cause some of the air to be dragged with them, so that an "electrical" wind is observed flowing from the point. The wind is accompanied by a mechanical reaction $(-F)$ of the point in the opposite direction to that of the wind itself. This reaction is found to be considerably greater for a positive point than for a negative point, the potential being of the same absolute value in each case.

In order to calculate the force (F) acting in any direction, we will consider the ions already formed in the neighborhood. We will assume that the electric field is uniform for the solid angle w. (In actual practice the discharging points consist of asbestos fibres or mica edges interwoven with the conducting wire electrode. If a large number of asbestos fibres are discharging along the wire, w will be quite small.) Let the point be discharging in the z direction and let the density of ions at any point in the solid angle w be ρ_1, the value of the electric field at the point E_z. The stream of ions will be supposed to be confined to the angle ω. The actual appearance indicates that this is the form of the discharge.

The force (F) acting on the ions in the z direction is:

$$F = \int\int\int Ez\, \rho\, dx\, dy\, dz$$

the integration being extended through the angle APB. If V_z is the z component of the ions' velocity and k their mobility, then,

$$Vz = kEz$$

The current (i) through any cross section of w is:

$$i = \int\int Vz\, \rho\, dx\, dy$$

Considering k to be constant,

$$F = \int\int\int \frac{Vz}{k} \rho\, dx\, dy\, dz = \frac{i}{k} \int dz$$

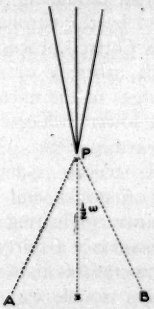
From the above it is seen that the reaction, $-F$, on the point varies inversely as k, if the current is constant. Experiments with single points discharging to electrodes of various forms indicate that the above formula is approximately correct.

For our present purpose the ions having the mobility k are the small ions produced by secondary ionization in large numbers near the discharging electrode, where E_s is very large.

According to the above formula, the force F increases as k decreases or as M increases. F is also increased by increasing the value of i. The aim in electrical precipitation is to increase F, and this is most easily done by increasing i, which in turn depends on increasing ρ.

Now suppose any particle of dust or smoke is placed near the point P in the angle APB (Fig. 2), subtending an angle δw from

FIG. 2.



the point P. The force F_1 acting in this particle due to the ionic streams will be $\frac{F\delta w}{w}$, the ionic stream being supposed to be within the solid angle w. From this formula one has the value of the force acting on any dust or smoke particle:

$$F_1 = \frac{i\delta w}{kw}\int dz$$

There are then three forces which aid in driving the suspended particles towards the grounded electrode: (1) the impact of the ionic streams; (2) the impact of the neutral gas particles constituting the electric wind—a sort of hydrodynamic action;

and (3) the direct action of the electric field on the smoke particles when they carry a free charge. These forces are of different degrees of effectiveness for different positions of the smoke particle. In ordinary conditions of ionization the charge on the smoke particles would be small. In electrical precipitation where the ionic streams are flowing in the same direction and contain ions of a single sign, the charge on the smoke particles may become very large and the direct action of the electric field may be the most important force near the end of the smoke particles' path. (This is the view held by Dr. Rosa. In order to test this view, experiments are being made on the charge carried by the smoke particles under these conditions.)

(*a*) *The Cottrell*[16] *Method.*

The kind of discharge used for precipitation may be of two types,—a point discharge producing an electrical wind, or a stream of ions produced by the corona discharge. One of the essential features of the Cottrell process is the use of wire electrodes interwoven with asbestos or mica. Fine threads of asbestos or the sharp edges of the mica cause the production of secondary ionization at lower voltages than could be obtained from the wire electrodes themselves. For this reason it is not necessary to have such accurate spacing of the electrodes to prevent the formation of sparks and arcs. There is usually sufficient moisture or other conducting deposits on the asbestos or the mica to make the surface a fairly good conductor at high potentials. At high temperatures it is difficult to keep the surfaces conducting, and this trouble was experienced in the plant set up by Balaklala Copper Company. The discharging or active electrode is charged negatively, and the suspended matter in the gas is driven to the grounded electrode.

At the plant installed by the Balaklala Copper Company, situated at Coram, Calif., the voltage was stepped up from 2,300 to from 25,000 to 30,000 volts and was then rectified. The rectifying commutators were made so that about 30 or 40 degrees of the maximum part of the wave form was used.

In the Coram plant the active electrodes consisted of two No. 10 iron wires twisted about mica strips about a centimetre wide

[16] See Cottrell, *J. Ind. and Eng. Chem.*, 3, 8, 1911.

and with serrated edges. A treating unit consisted of eight rows of these electrodes, twenty-four electrodes being in a row. The units were 30 feet in length, 10 feet wide, and 10 feet high. The grounded electrodes were made of No. 10 sheet iron 6 inches wide and 10 feet high, and were connected directly to the frame of the units themselves. The active electrodes were kept stretched by springs between a system of bus bars supported outside the precipitating chamber on wooden insulators; in order to prevent a deposit from short-circuiting the insulators, a current of air could be passed over the insulators into the precipitation chamber, thus preventing any of the fumes from coming in contact with the insulators. The cleaning of the electrodes was done by mechanical shaking.

At the Coram plant three units were kept charged by a single rectifier using from 0.3 to 0.4 ampere of current. Each unit treated about 10,000 cubic feet of fumes per minute, the fumes passing through about 30 feet of the electrical field with a velocity of about 5 feet per second. The suspended matter remains about 6 seconds in the electrical field. About 30 pounds of fumes were precipitated per hour per unit.

(7) THE CORONA DISCHARGE.

The luminous discharge from wires and cables carrying a high voltage current has been called the corona discharge by electrical engineers. The lowest voltage gradient per centimetre at which a luminous discharge begins to appear (the "critical corona" voltage, *Ec*) has been identified as being the same as that at which line losses of power begin to increase rapidly (*Ee*) and secondary ionization appears at the conductor ("critical ionization" voltage, *Ei*). The production of secondary ionization in the neighborhood of the conductor causes streams of ions to flow from it into the surrounding gas, producing effects that are similar to those produced by the electrical wind due to a point discharge. The following is a brief summary of the properties of the corona discharge:

(1) In air the positive corona consists of fine branching, bluish-purple brushes darting a centimetre or more from the wire. When the ionic current density is great enough there is a thin, bluish-purple film covering the wire. This is accompanied by a slight buzzing noise. The positive corona is not greatly affected

by the presence of dirt. The brush discharge consists of straight stems of considerable luminosity, from which dart forth twig-like, purplish-violet branches. The pitch of the hissing sound produced depends on the proximity of neighboring conductors.

(2) The negative corona consists of bright, stationary, reddish discharges from 3 to 5 mm. in length. No bright film is present. A loud buzzing noise is produced. The negative brush is but slightly influenced by the presence of surrounding conductors. Dirt decreases the noise and causes the discharge to become more localized.

(3) The presence of asbestos or mica causes the discharge to take place from a comparatively small number of points, the discharge being similar to that of (1) or (2), according to the sign of the charge.

(4) The corona due to an alternating voltage being impressed on the conductor consists of a violet-purplish glow extending several millimetres from the conductor. Whitehead finds that the corona appears and disappears at almost the same voltage for the different parts of the alternating voltage curve. The ions taking part in corona formation are very short-lived.

Placing a glass tube (2 mm. in diameter) over the corona-covered wire decreased the intensity of the corona. The glass tube is surrounded by a pale luminosity about a centimetre in diameter. A loud, sizzling sound is produced.

(5) The introduction of an oscillatory spark in series with the corona discharging circuit has been found to increase the positive brush discharge very greatly. Using a No. 28 steel wire in an 8-inch cylinder, it is possible to obtain a brush discharge between the wire and the cylinder when the effective alternating-current voltage is less than 30,000 volts. The oscillatory spark gap should only be a few millimetres in length.

(6) The corona discharge produced by current from the rectifier is very similar to that described in (5). This is due to the fact that the current must flow across the air gaps of the rectifier. The luminosity about the corona-producing conductor is much less than is the case when no air gaps are in the circuit.

(7) On high-voltage transmission lines, Peek[17] and others have shown that smoke, fog, sleet, rain, and snow increase the

[17] *Proc. A.I.E.E.*, 30, p. 1491, 1911.

loss of energy due to corona discharge. *Ee* is lowered, the effect due to snow being much greater than that due to rain. The corona discharge does not prevent the formation of sleet upon the wires.

(8) A heavy wind has been found to be without effect on *Ee*. In the laboratory Whitehead has altered the velocity of the air currents past the corona-covered conductor without changing the value of *Ei*. An air velocity as great as 150 feet per minute was used.

(9) Humidity has been found to have no effect on corona formation. In the laboratory the writer has observed no change in the appearance of the corona as described in (4) and (5) when the region of discharge was filled with water spray.

(10) Rise of temperature lowers the value of E_i, according to Whitehead.[18] He gives a case where E_i is lowered from 71.4 to 66.3 kilovolts by a rise of temperature from 7.4° to 41° C.

(11) The critical surface electrical intensity in kilovolts E_i is related to the diameter of wire (d in cm.) at 76 cm. pressure and 21° C. as follows:

$$E_i = 32 + \frac{13.4}{\sqrt{d}}$$

An example[19] of the use of the corona type of discharge is the application of electrical precipitation of the cement dust from the kilns of the Riverside Portland Cement Works, at Riverside, Calif. In this plant the gases to be treated are at temperatures of about 450° C. The cement dust is non-conducting, so that no conducting surface would be formed over the mica or asbestos. The use of the corona discharge requires higher voltages than those used in the point discharge. These voltages range in the neighborhood of 40,000, according to Cottrell. The clearance of dust is in general from 95 to 98 per cent. The construction of the treating units at Riverside is almost identical to those used at Coram. At Garfield, Mr. Rathbone is experimenting on the use of cylindrical electrodes. These produce a much more uniform electrical discharge and subject the suspended matter in the gas to a much more uniform treatment. The diameter of the cylinders is 5 inches.

[18] *Trans. A.I.E.E.*, 27, 1910; 30, p. 1097, 1911.

[19] Cottrell, *Cement and Eng. News*, vol. 24, p. 99, 1912.

(8) THE PRECIPITATION OF COAL SMOKE.

(1) The presence of a small amount of dirt lowers the critical voltage of corona formation, the corona appearing as bright scintillating points. The presence of a coating of soot upon the surface of the conductor affects the appearance of the corona but little.

(2) The electrical discharges that take place in coal smoke are apparently of the same nature as in air. The fibrous brush discharge, characteristic of the positive corona, is distinctly visible. The glow discharge is of a blue color. This is not due to absorption of violet light by the smoke, for a purplish-violet glow loses none of its characteristic color when viewed through smoke.

(3) The presence of smoke causes an increase in the difference of potential between the inside corona wire and the outside cylinder, while the ionization current is decreased. Schmidt has noted the same effect in the case of cement dust. This is due to the great decrease in the ionization of the flue gases due to the presence of smoke.

(4) Coal and oil smoke is precipitated in the same way as the various kinds of fumes. When precipitation is produced by a point discharge, a unidirectional current is much more effective than an alternating one. (An alternating current produces a greater amount of precipitation when there are rapid oscillations produced in it by a series spark gap.) This is probably due to the fact that the pressure of the electrical wind is very much greater from an electrode kept at a constant potential than from one charged by an induction coil or a transformer.

(5) Very little difference was obtained in the precipitation of dense coal smoke in cylindrical pipes, between an alternating current and unidirectional current, when a similar corona form of discharge was used. The precipitation seemed to be comparatively greater for a dense smoke than for light smoke. From this it would follow that dilution of the fume- or smoke-laden gases should be prevented as much as possible.

(6) The similar action of an alternating-current corona and a unidirectional-current corona as a precipitating agent is to be expected if the corona is practically the same for both parts of the wave form, as was found to be the case by Whitehead.

(7) Clearances of 90 and 95 per cent. have been obtained by passing extremely dense smoke through a corona discharge less than 2 feet in length. These experiments indicate that the greatest efficiency of precipitation can be obtained by keeping the suspended matter from being diluted and by exposing them as much as possible to the streams of ions flowing from the corona by passing the gases through a uniform discharge. Shadows can be obtained from objects placed near the collecting electrodes, indicating that the matter being deposited moves in straight lines.

(8) Some kinds of smoke show selective precipitation, a thin cloud of white or bluish particles coming out from the corona discharge. Part of this is water vapor which may have condensed after the carbon and tarry matter had been precipitated. Whether this selective action is due to a difference in the size of the suspended particles or due to a difference in their composition has not yet been determined, although the former view is the more probable.

(9) The hot gases as they leave the furnace contain a very great number of ions of comparatively great mobility, and the ionization current due to these ions may be quite large. This current has been described in a previous part of this paper. The presence of smoke decreases the number and mobility of these ions very greatly, and hence decreases the current due to this cause. This effect is given in (3). Besides this ionization current, there is the current due to the ions produced in the corona discharge itself. In the section on the electrification of dust and sprays it was shown that these ionic currents charge the suspended particles. It is doubtful, however, if the presence of the particles causes any material decrease in the current due to these ionic streams.

(10) In the section upon the electrical wind it was shown that the force due to ionic streams increased with the increase in the size of the particles. On the other hand, the force on a particle due to the action of the electric field on its charge is independent of the size of the particle. For very fine particles the latter force may give sufficient velocity to be of importance, but for ordinary smoke and dust particles the force due to the ionic streams is the preponderating one.

(11) Using Ryan's formula for the loss of power due to

corona discharge, we find that this is practically the amount of energy actually used in the precipitating plant at Coram. It is very probable that no more nor less energy is required for precipitation than that necessary to produce the corona ionization current.

(12) Precipitation of coal smoke was produced in a 3-inch cylinder (4 feet in length) placed in a horizontal position. The active electrode consisted of a No. 28 steel wire. An alternating voltage was used. The cylinder was heated to redness on the under side by a row of Bunsen burners. Precipitation was then qualitatively just as complete, the soot being deposited upon the upper surface of the cylinder. This experiment would indicate that temperature does not play much of a rôle in electrical precipitation. On the other hand, the state of ionization of the gases probably does play a very important part, as was shown in the measurements on sparking potentials.

(13) The character of the corona discharge is probably very greatly affected by the resistance, inductance, and capacity of the circuit when air gaps are introduced by using a rectifier. The writer hopes to investigate some of the effects produced by the constants of the circuit upon the nature of the ionic streams produced in the corona discharge.

(14) The application of electrical precipitation to the smoke problem has not as yet been tried on a commercial scale. Laboratory experiments indicate that the problem is essentially the same as that of the precipitation of fumes and dust. The use of cylindrical electrodes results in a much more uniform electrical discharge if the active electrode is made the axis of the cylinder. While the brush form of discharge from points is only a good precipitating agent when the current of gas is small, the corona discharge is effective for much greater velocities of the gas containing the suspended particles. Under these conditions the suspended particles need remain but a short time in the region where the corona discharge is taking place so that the size of the precipitation chamber can be greatly reduced. The mechanical difficulties of keeping the electrodes properly adjusted and cleaned are probably as great as the electrical part of the problem.

(9) SUMMARY.

(*a*) The effect of the polarization of suspended particles in a gas results in the aggregation of the particles and increases

the ease with which the suspended matter can be removed from the gas by settling or by centrifugal means.

(*b*) Suspended particles in a gas can be ionized and may then be removed from the gas by the action of the electric field. Examples are given of the ionization of particles or various kinds of spray and dust. It is shown how various kinds of smoke-deposit patterns are formed by electric fields that are not intense enough to produce secondary ionization and ionic streams.

(*c*) The presence of suspended particles in a gas increases the rate of recombination of the ions in the gas. Smoke or fumes thus greatly reduce the ionization in gases coming from furnaces, and this reduces the ionic current between spark electrodes placed in the gas. This property of smoke or fumes may be used to indicate their presence in a gas.

(*d*) One of the most effective actions of an electrical discharge in precipitating suspended matter from a gas is that of the force acting upon the suspended particles due to the ionic currents flowing through the gas. These ionic currents are produced by the action of the electrical field upon the ions formed by secondary ionization. The secondary ionization may be produced by a point or by a corona discharge.

(*e*) A brief account is given of the plants that have been built for precipitating the fumes from copper smelters and the dust from cement plants. These were visited by the writer during the summer of 1911.

(*f*) A brief account is given of experiments made by the writer upon the precipitation of carbon smoke. Up to the present practically nothing has appeared in the literature concerning the electrical properties of coal smoke.

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Illuminating Engineering Society.—The Sixth Annual Convention will be held at Hotel Clifton, Niagara Falls, September 16th to 19th. The programme includes papers by Dr. C. P. Steinmetz, Mr. George S. Barrows, Dr. E. P. Hyde, Mr. F. A. Benford, Dr. P. G. Nutting, and others. Inspection tours will be made to power-houses and other development enterprises in the vicinity of Niagara Falls.

Canadium, a New Metal. ANON. (*The Metal Ind.*, ix, 12, 508.)—Canadium was discovered by Mr. A. G. French, in a deposit of platinum metals in one of the gold mines in British Columbia. Canadium is sometimes found isolated and sometimes combined. Canadium is a beautiful white metal, a little softer than gold or silver and melts at a little lower temperature. It does not tarnish from damp, and is not affected by sulphides or iodine. It is much more brilliant, when burnished, than silver or palladium. It is electro-negative to silver, gold and palladium, and is not oxidizable even in the oxidizing flame of a blowpipe. It occurs in the form of metallic, semi-crystalline grains, small rods and scales.

Corrosion of Brass. P. T. BRUHL. (*The Metal Ind.*, ix, 11 and 12.)—This is a well considered paper on the corrosion of brass, with special reference to condenser tubes. The conclusions drawn are:—1. That the presence of air, or an increase of temperature up to a certain point, accelerates corrosion. 2. That iron, nickel and small amounts of lead are injurious. That tin up to 1 per cent., large amounts of lead, and aluminum diminish corrosion. 3. That the inlet pipe and condenser plates should be made of brass. 4. That the condenser should be protected against stray currents. 5. That protective coatings are not recommended. 6. That "spills" greatly increase corrosion. 7. That the tubes should be flushed with clean water after use.

Melting of Carbon. W. BORCHERS. (*Metallurgie*, ix, 230.)—Using very pure carbon rods supported between the poles of an electric furnace, it is maintained that carbon shows no tendency to melt at the highest temperature attainable. The effects produced are due to the expansion and loosening of the mechanical structure present even in the purest rods, causing them to become less coherent and to break.

The National Bureau of Standards in its general investigation of structural materials is engaged, among other things, in the determination of the physical properties of concrete. At the suggestion of engineers and others, the Bureau of Standards is investigating the cause of cracking in concrete structures, where the necessity for expansion and contraction joints is questioned. For this purpose, reference marks were placed on some of the typical old and new concrete work in Wayne County, Michigan, also at Greenwich, Connecticut. Measurements will be taken from time to time during the summer and winter to determine the expansion or contraction in the concrete caused by temperature variations and the changes of volume which take place during the hardening of the concrete. Similar reference marks are being placed on the lock walls of the Panama Canal and various other structures, from which valuable information will be obtained.

NUTATION AND THE MONORAIL CAR.[1]

BY

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THE Brennan apparatus for the stabilization of the monorail car is subject to the phenomena of nutation, as of course are all rotating bodies. So far little attention seems to have been paid to this part of the theory. That the nutational vibration may very possibly reach considerable magnitude and violence is suggested by the performance of a common laboratory model shown in Fig. 1. If a weight be attached suddenly, so as to exert a force in the direction of the arrow, the resulting nutation is very marked, having considerable amplitude and a period so long that the undulatory nature of the combined precession and nutation is very apparent. This behavior is due to the fact that the moment of inertia, about the axis of precession, of the mass which partakes of the precession is large compared with the angular momentum of the rotating wheel. A similar situation obtains in the case of the monorail car. Adjustments of the inclination of the car to a change of load or other external forces are accomplished by a precessional motion which takes the form of a rotation of the car and contents about the rail as the axis of the precessional motion. The moment of inertia of the car and its contents with respect to the rail is a large quantity, and it ought not to be presumed that the nutational vibration can be disregarded. The following study of this matter results in formulas which describe the combined precessional and nutational motion, and numerical examples are worked out for an assumed case to illustrate the application of the formulas and to show how far this portion of the theory will govern the design of the gyrostabilizing system.

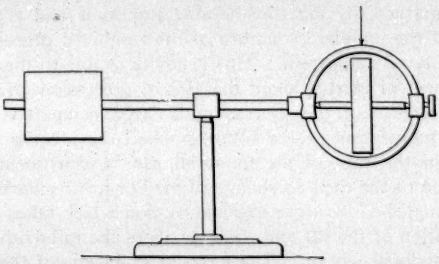
Fig. 2 represents in schematic outline the car and stabilizing device. The pair of flywheels with axles horizontal which Mr. Brennan uses are replaced by a single flywheel with vertical

[1] Communicated by the Author.

axle. This is undoubtedly the more satisfactory arrangement in practice as well as the more convenient for theoretical investigation.

The process of readjustment of the equilibrium of the car is as follows: Suppose the car to be standing upon the track as shown in the figure with the axle of the flywheel vertical and with no external disturbing forces acting. Then suppose a disturbing force applied at A so as to produce a couple Ca which tends to overturn the car. This disturbing couple will be resisted by the gyro-action of the flywheel so that the car will not tip to any considerable extent in the direction in which it is urged by the disturbing couple. This statement implies the rigidity of materials and in particular the absence of spring mounting of the gyro-apparatus upon the car or the car upon the trucks.

FIG. 1.



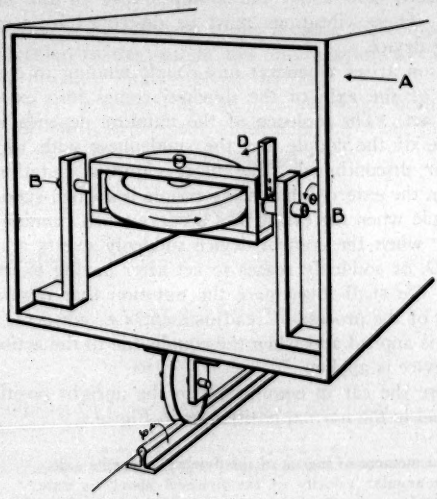
The effect of such springs is by no means unimportant, but it should be treated in a separate discussion after the simpler case now under consideration has been disposed of.

The disturbing forces may be imagined to come into existence suddenly or gradually. In either case the gyro-resistance exerted by the flywheel to prevent the car from yielding to the disturbance will be accompanied by a precession of the flywheel about the axis BB, and a nutation. The latter is a periodic motion and may be resolved into two components, one a periodic angular motion of the flywheel and its frame about the axis BB, and the other a periodic angular motion of the car and its contents about the centre of the circular section of the rail.

The precession would soon carry the wheel and frames

through an arc of 90° about the axis *BB* and the flywheel would then offer no further resistance to the disturbing forces, allowing the car to tip over to the left. To prevent such an event a control device is provided. This device exerts a force at *D*, which produces a couple C_c tending to turn the flywheel and frame about the axis *BB*. This couple, due to the action of the control device, may be thought of as coming into existence gradually or suddenly. In either case it results in a combined precessional and nutational motion. The precession turns the car with its contents about the centre of the rail toward the right, and the nutation

FIG. 2.



which is periodic may be resolved into two components, one a periodic rotation of the flywheel and frame about the axis *BB*, and the other a periodic rotation of the car and its contents about the rail.

So soon as the precessional motion described in the last paragraph has turned the car far enough to the right so that the couple due to the weight of the car overbalances somewhat the disturbing couple C_d, the control devices cease to act, the car

ceases to turn toward the right and the flywheel returns toward its normal position. This return of the flywheel toward the normal position is due to the overbalancing of the disturbing couple by the gravity couple. As the flywheel approaches its normal position a small force exerted by the control device at D in the direction opposite to that shown in the figure turns the car by precession slightly to the left into a position such that the gravity couple balances the disturbing couple and the car is in equilibrium again with the flywheel in its normal position.

Thus we have described the process of readjustment of equilibrium of the car to any disturbing force, except that nothing has been said about the disappearance of the nutational motions. These vibrations must be destroyed by some shock absorbing device.

Nutation arises whenever any couple tending to change the direction of the axle of the flywheel comes into existence or ceases to act. The violence of the nutation depends upon the magnitude of the couple and the suddenness with which it is applied or discontinued. The most vigorous nutation would arise when the external disturbing couple is applied suddenly (as for example when the car strikes a curve when running at high speed) or when the control device suddenly exerts a powerful force at D, or suddenly ceases to act after having exerted such a force. We shall investigate the nutation that occurs at the beginning of the process of readjustment, *i.e.*, when the disturbing force is applied and when the couple due to the action of the control device is applied.

Suppose the car in equilibrium in the upright position with the flywheel in the normal position as in Fig. 2.

Let I = moment of inertia of the flywheel about its axle.
ω = angular velocity of the flywheel about its axle.
$N = I\,\omega$ = angular momentum of flywheel.
J = moment of inertia of car and contents about rail.
j = moment of inertia of flywheel and frame about the axis BB.
Q = weight of car and contents in pounds.
H = height of centre of gravity of car and contents above the rail axis.
$C_1 = K$ = disturbing couple applied instantly.
θ = angular displacement, from normal position, of flywheel and frame about the axis BB.
φ = angular displacement of car and contents about the axis of the rail.

The equations of motion are then

$$J\frac{d^2\phi}{dt^2} = K + QH\sin\phi - N\cos\theta\,\frac{d\theta}{dt}$$

$$j\frac{d^2\theta}{dt^2} = N\cos\theta\,\frac{d\phi}{dt}$$

The last term in each equation is due to the gyro-resistance (see Spinning Tops, etc., by H. Crabtree, p. 44, or Theorie des Kreisels, by Klein and Sommerfeld, vol. iv, par. 1). The factor cos appears in the first of these terms since the axis of the couple $N\frac{d\theta}{dt}$ makes the angle θ with the rail. The factor cos θ appears in the second of these terms because the component of N perpendicular to the rail is the only portion of it that is effective in resisting rotation about the rail.

Since we are investigating the nutation which occurs at the beginning of the readjustment of equilibrium when the angles φ and θ are very small we may set

$$\sin\phi = \phi$$
$$\cos\theta = 1$$

and the equations become

$$(1)\qquad \frac{Jd^2\phi}{dt^2} = K + QH\phi - \frac{Nd\theta}{dt}$$

$$j\frac{d^2\theta}{dt^2} = N\frac{d\phi}{dt}$$

The solution of these equations is of the form

$$(2)\qquad \phi = a\sin\lambda t + b\cos\lambda t + ct + d$$
$$\theta = a'\sin\lambda t + b'\cos\lambda t + c't + d'$$

The initial conditions are

$$t = 0 \qquad \phi = 0 \qquad \theta = 0$$

$$\frac{d\phi}{dt} = 0 \qquad \frac{d\theta}{dt} = 0$$

$$\frac{d^2\phi}{dt^2} = \frac{K}{J} \qquad \frac{d^2\theta}{dt^2} = 0$$

The remaining relations used in determining the constants are

obtained by substituting the expressions (2) for φ and θ in (1) and placing the coefficients of the various powers of t and of $\sin \lambda t$ and $\cos \lambda t$ separately equal to zero. We find:

$$a = 0 \qquad a' = -K\frac{N(Jj)^{\frac{1}{2}}}{(N^2-QHj)^{\frac{3}{2}}}$$

$$b = -K\frac{j}{N^2-QHj} = d \qquad b' = 0$$

$$c = 0 \qquad c' = K\frac{N}{N^2-QHj}$$

$$\lambda = \sqrt{\frac{N^2-QHj}{Jj}} \qquad d' = 0$$

The solution is therefore

$$\varphi = -K\frac{j}{N^2-QHj}\cos\sqrt{\frac{N^2-QHj}{Jj}}\,t + K\frac{j}{N^2-QHj}$$

(3)

$$\theta = -K\frac{N(Jj)^{\frac{1}{2}}}{(N^2-QHj)^{\frac{3}{2}}}\sin\sqrt{\frac{N^2-QHj}{Jj}}\,t + K\frac{N}{N^2-QHj}\,t$$

The constant term in the expression for φ is called the "dip." It is the amount that the flywheel would yield to the disturbing couple if precession were steady, *i.e.*, if nutation were absent. The term multiplied by t in the expression for θ is the rate of steady precession corresponding to the disturbing couple K. The periodic terms represent the nutation. The periods are identical, but the amplitude of angular vibration of the flywheel and its frame about the axis BB is greater than the amplitude of vibration of the car about the rail, by the factor

$$N\sqrt{\frac{J}{j(N^2-QHj)}}$$

This is a matter of importance in the design of the control device. Mr. Brennan's letters patent concerning the control device proceed upon the assumption that the rotation of the wheel and frame about the axis BB is a steady precession, whereas in fact it will be a very jerky motion if the disturbing couple is large

and quickly applied, as would be the case when a car strikes a curve at a high rate of speed.

The question arises naturally as to the degree of suddenness with which the disturbing force must be applied in order that the nutational vibration may approximate the value given by this solution made upon the basis of instantaneous application. To answer this question let us insert in the differential equations of condition the expression kt for the disturbing couple Ca instead of the expression K used above and solve the modified equations. They are, in the approximate form

$$J\frac{d^2\phi}{dt^2} = kt + QH\phi - N\frac{d\theta}{dt}$$
$$j\frac{d^2\theta}{dt^2} = N\frac{d\phi}{dt} \tag{1a}$$

The solution is now of the form

$$\phi = a\sin\lambda t + b\cos\lambda t + ct^2 + dt + e$$
$$\theta = a'\sin\lambda t + b'\cos\lambda t + c't^2 + d't + e' \tag{2a}$$

The initial conditions are

$$t = 0 \quad \phi = 0 \quad \theta = 0$$
$$\frac{d\phi}{dt} = 0 \quad \frac{d\theta}{dt} = 0$$
$$\frac{d^2\phi}{dt^2} = 0 \quad \frac{d^2\theta}{dt^2} = 0$$

These, with the equations arising from the substitution of values of φ and θ given in (2a) into (1a), give for the values of the constants:

$$a = -k\frac{Jj^2}{N^2 - QHj} \qquad a' = 0$$
$$b = c = 0 \qquad b' = k\frac{NJj}{(N^2 - QHj)^2}$$
$$d = k\frac{j}{N^2 - QHj} \qquad c' = \frac{k}{2}\frac{N}{N^2 - QHj}$$
$$e = 0 \qquad d' = e' = 0$$
$$\lambda = \sqrt{\frac{N^2 - QHj}{Jj}}$$

The solution is therefore

$$\text{(3a)} \qquad \phi = -k\frac{J^{\frac{1}{2}}j^{\frac{3}{2}}}{(N^2-QHj)^{\frac{3}{2}}}\sin\sqrt{\frac{N^2-QHj}{Jj}}\,t + k\frac{j}{N^2-QHj}t$$

$$\theta = k\frac{NJj}{(N^2-QHj)^2}\cos\sqrt{\frac{N^2-QHj}{Jj}}\,t + \frac{k}{2}\frac{N}{N^2-QHj}t^2$$

The term in the expression for φ which represents the dip is now a linear function of the time, as it should be since the dip is proportional to the disturbing force, which increases with the first power of the time. The second term in the expression for θ is of the second degree with respect to the time since the precession proceeds at an accelerated rate. The terms representing the nutation have the same period as in the former solution, as they should, since the period of the nutation depends upon the mass and dimensions of the car and flywheel and the angular momentum of the wheel. The amplitudes differ from those of the previous solution in that both are multiplied by the factor:

$$\frac{k}{K}\sqrt{\frac{Jj}{N^2-QHj}}$$

which the numerical example will show to be a small quantity unless k is very large as compared with K; that is, unless the disturbing force reaches its maximum effect in a small fraction of a second, this second solution will represent the facts more closely than the preceding one.

So far we have assumed the control device to be inactive. We shall now proceed to investigate the nutational vibrations that would be produced by sudden application of the couple which we call C_c due to the action of the control device. It will be remembered that the control device exerts its force after the application of the external disturbing force, so that the vibrations due to this latter force would perhaps be in progress when those due to the action of the control device come into being. However, to avoid unnecessary complication we shall assume that the vibrations due to the application of the external disturbing force have been damped out and a state of steady precession reached before the control device begins to act. The flywheel and car are supposed to be in the position shown in Fig. 2, with

the disturbing force acting at A and the flywheel executing the corresponding precessional motion about the axis BB.

The approximate equations of motion for the cases corresponding to the two discussed above are:

For instantaneous application of the couple $C_c = K_c$

$$J\frac{d^2\phi}{dt^2} = K + QH\phi - N\frac{d\theta}{dt}$$
$$j\frac{d^2\theta}{dt^2} = K_c + N\frac{d\phi}{dt} \tag{1b}$$

For gradual application of the couple $C_c = k_c\, t$

$$J\frac{d^2\phi}{dt^2} = K + QH\phi - N\frac{d\theta}{dt}$$
$$j\frac{d^2\theta}{dt^2} = k_c t + N\frac{d\phi}{dt} \tag{1c}$$

The initial conditions are:
For the first case,

$t = 0$ $\quad \phi = 0$ $\quad \theta = 0$

$$\frac{d\phi}{dt} = 0 \qquad \frac{d\theta}{dt} = \frac{KN}{N^2 - QHj}\ *$$
$$\frac{d^2\phi}{dt^2} = 0 \qquad \frac{d^2\theta}{dt^2} = \frac{K_c}{j}$$
$$\frac{d^3\phi}{dt^3} = -\frac{N}{J}\frac{k_c}{j} \qquad \frac{d^3\theta}{dt^3} = 0$$

For the second case,

$t = 0$ $\quad \phi = 0$ $\quad \theta = 0$

$$\frac{d\phi}{dt} = 0 \qquad \frac{d\theta}{dt} = \frac{KN}{N^2 - QHj}$$
$$\frac{d^2\phi}{dt^2} = 0 \qquad \frac{d^2\theta}{dt^2} = 0$$
$$\frac{d^3\phi}{dt^3} = 0 \qquad \frac{d^3\theta}{dt^3} = \frac{k_c}{j}$$

* Obtained by differentiating the nonperiodic portion of the expression for θ eq. 3.

The solutions are: for the first case,

$$\text{(3b)} \qquad \phi = K_c \frac{N(Jj)^{\frac{1}{2}}}{(N^2-QHj)^{\frac{1}{2}}} \sin\sqrt{\frac{Jj}{N^2-QHj}}\, t - K_c \frac{N^2-QHj}{N} t$$

$$\theta = -K_c \frac{N^2 J}{(N^2-QHj)^{\frac{3}{2}}} \cos\sqrt{\frac{Jj}{N^2-QHj}}\, t - \frac{K_c}{2} \frac{QH}{N^2-QHj} t^2 + \frac{KN}{N^2-QHj} t + K_c \frac{N^2 J}{(N^2-QHj)^2}$$

for the second case,

$$\text{(3c)} \qquad \phi = -k_c \frac{NJj}{(N^2-QHj)^2} \cos\sqrt{\frac{Jj}{N^2-QHj}}\, t - \frac{k_c}{2} \frac{N}{N^2-QHj} t^2 + k_c \frac{NJj}{(N^2-QHj)^2}$$

$$\theta = -k_c \frac{N^3 J^{\frac{3}{2}} j^{\frac{1}{2}}}{(N^2-QHj)^{\frac{3}{2}}} \sin\sqrt{\frac{Jj}{N^2-QHj}}\, t - \frac{k_c}{6} \frac{QH}{N^2-QHj} t^3 + \left[k_c \frac{N^2 J}{(N^2-QHj)^2} - K \frac{N}{N^2-QHj} \right] t$$

The vibration periods are identical with those obtained in the former solutions but the amplitudes are greater for the same applied couples. The amplitude of the vibration in the co-ordinate θ is in each case equal to that in the co-ordinate φ multiplied by the factor

$$N\sqrt{\frac{J}{j(N^2-QHj)}}$$

The formulas 3, 3a, 3b, 3c indicate the performance of the car and flywheel when the wheel is near the normal position, *i.e.*, $\theta = 0$. When the flywheel is in any other position the formulas should be modified by the substitution of $N \cos \theta_0$ for N, where θ_0 is the value of θ at the instant the couple that produces the nutation is applied or discontinued. That this is the case will be clear when the more rigorous form of the equations of condition is recalled (p. 269). Instead of setting

$$\cos\theta = 1$$

we set

$$\cos\theta = \cos\theta_0$$

which is a better approximation for this case.

As an example of the application of these formulas let us assume that a car of the weight and dimensions of a standard sleeping car is built to run on one rail with a Brennan stabilizing device of the form shown in Fig. 1.

Suppose the weight and dimensions of the car to be such that

$Q = 150{,}000$ pounds.
Distance of centre of gravity of car above centre of rail bulb $= 6$ feet.
Radius of gyration of car about gravity axis parallel to rail $= 5$ feet.

Let the mass of the flywheel be taken equal to 5 per cent. of the mass of the car in accordance with an estimate ascribed to Mr. Brennan, and suppose its radius of gyration to be 6 feet. Such a wheel if made of nickel steel might run at a rate of 1600 r.p.m. We have upon this basis the following values of quantities appearing in the formulas:

$$N = 351200.$$
$$J = 284000.$$

Let us assume $j = \frac{2}{3} I = 1398.$

Then
$$QHj = 1.258 \times 10^9$$
$$N^2 - QHj = 1.220 \times 10^{11}$$

Now suppose this car to be travelling at a rate of 120 miles per hour, and to enter upon a two degree curve over a spiral 400 feet long. The moment of the centripetal force corresponding to the two degree curve would be

302200. foot-pounds.

The time spent upon the spiral would be

2.273 seconds

When the car strikes the spiral the disturbing force would grow at a rate of

132900. foot-pounds per second,

which is the value of k in formula 3a.

Inserting these values in formula 3a, we have for the amplitudes and period of the nutational vibration of the car about the rail

$$\text{Amplitude} = \frac{J^{\frac{1}{2}} j^{\frac{1}{2}}}{(N^2 - QHj)^{\frac{1}{2}}} = 0.^{\circ}05$$

$$\text{Period} = 2\pi \sqrt{\frac{Jj}{N^2 - QHj}} = 0.^{s}36$$

If the control device were to act so as to incline the car inward at a uniform rate (neglecting the nutational vibration) as the car traverses the spiral its couple would have to be applied instantly with full force and remain constant while the car is upon the spiral. The magnitude of the couple that would be required is obtained from the first of equations 3b as follows. Omitting the periodic term we have

$$\frac{d\phi}{dt} = -K_c \frac{N}{N^2 - QHj}$$

$$K_c = -\frac{N^2 - QHj}{N} \frac{d\phi}{dt}$$

If φ represent the inclination with which a car should round a curve of radius r at v miles per hour, we have the well known relation

$$\tan \varphi_1 = \frac{v^2}{gr}$$

where g is the acceleration due to gravity. For the two degree curve at 120 miles per hour, we find

$$\phi = 18.^{\circ}56$$

and dividing this by the time spent upon the spiral we have

$$\frac{d\phi}{dt} = \frac{18.56}{2.273} \times \frac{1}{57.3} = 0.1425 \text{ radians per sec.}$$

which gives

$$K_c = 49{,}510. \text{ ft. lbs.}$$

The amplitude of the nutational vibration of the car corresponding to the sudden application of such a couple is obtained by substituting in the first equation of 3b, namely

$$\text{Amplitude} = K_c \frac{N(Jj)^{\frac{1}{2}}}{(N^2 - QHj)^{\frac{1}{2}}} = 0.^{\circ}47$$

the period being as computed above $0^{s}.36$.

If the car were to vibrate in this manner a point twelve feet from the rail would perform a complete oscillation back and forth through a distance of

2.3 inches

in

0.36 second.

If it be assumed that the control device does not exert its couple instantly, but that the couple grows uniformly with the time at the rate of 50 foot tons per second, the amplitude of vibration would be only

0.°054

that is about one-tenth of the amplitude found above for the case of sudden application of the couple.

As regards the vibration of the wheel and frame about the axis *BB*, its amplitude for any given case is obtained from the amplitude of vibration of the car by multiplying by the factor

$$N\sqrt{\frac{J}{j(N^2-QHj)}} = 14.33$$

Thus the vibration of the wheel and frame about the axis *BB* would have a double amplitude of 13°.4 for the case of instantaneous application of the couple exerted by the control device.

These computations are presented to convey a more definite notion of the magnitudes involved. The assumed weight and dimensions of the car are about those of the heavier sleeping cars now in use. The curvature (two degrees) is conservative for present practice on the best roads. The 400 foot spiral is twice as long as would be used for a two degree curve. The amplitudes of nutational vibration prove to be small and the period is short. It would seem that all harmful effects could be prevented by taking proper care in the design of the car and stabilizing apparatus. The flywheel should be protected from couples that occur in the form of shocks. Means should be provided for damping out the nutational vibration that does arise and the design of the car springs should be such that the car would not vibrate upon them with a period approximating the period of the nutation. Finally, the design of the control device must take into account the vibratory nature of the motion

of the wheel and frame about the axis *BB*. As stated above, this seems to have been left out of account in the design recently patented by Mr. Brennan, which circumstance may very possibly lead to failure of the device to operate satisfactorily when severely taxed.

An incidental result of the numerical computations is to call attention to the very great couple that must be exerted by the control device. It can be shown that the control device must be prepared to exert a couple something like one-half as great as the maximum suddenly applied couple that the car is designed to resist.

Another incidental result of this study of the nutation is the indication given by equations 3c regarding suitable spiral approach to curves. The couple exerted by the control device should not be applied instantly, but should increase uniformly with the time in order that shock and excessive nutation may be avoided. This involves, according to equations 3c, a value of φ (that is an inclination of the car) which increases with the square of the time that has elapsed since the car entered upon the spiral. Since the inclination of the car should correspond to the curvature at each instant, it follows that the curvature ought to increase with the square of the distance measured along the track from the tangent section. In present steam railroad practice the curvature of the spiral increases approximately as the first power of the distance.

Condition of Existence of Arc between Carbon Poles. A. OCCHIALINI. (*N. Cimento*, 2 Ser. vi, 329.)—From a study of kinematographs of the electric arc between carbon poles, it is concluded that under ordinary conditions, with a cold anode, there are two distinct phases in the formation of the arc, the first having the character of a scintillation, the second, termed the *autonomous phase*, that of the arc proper. A cold anode is essential to the existence of the first phase, a hot anode for the second, so that the first prepares the necessary condition for the second. By using a rotating carbon disc as anode the first phase may be prolonged, since the anode does not get warm, and by starting with a hot anode the autonomous phase may be reached without any preliminary sparking. The gas emitted by the anode during the explosive phase gives a line spectrum, that produced during the autonomous phase a band spectrum.

THE TECHNIQUE OF GAS MANUFACTURE.[1]

BY

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UNTIL the Seventeenth Century the store of human knowledge as to the aëriform substances, which are now named gases, was practically confined to that of the more striking physical properties of the atmosphere and its corroding effect upon metals, especially when they were heated.

Van Helmont (1577–1674) was probably the first to understand the existence of aëriform bodies distinct from ordinary air. These he called spirit and in his writings he mentions bodies almost entirely composed of spirit which was fixed and solidified in them. To this spirit he gave the name of "gaz." According to Priestley, Van Helmont derived this name from the German word "geist," meaning spirit, but a later writer claims to have found a statement of Van Helmont connecting the word with "chaos."

Apparently the first published assertion as to the composition of the atmosphere was made in 1665 by Hooke, who stated that air contains a principle similar to, if not identical with, that of nitre. He also seems to have recognized that only a certain portion of the atmosphere is required to support combustion and respiration. The precise experiments on respiration published by Mayow in 1670 greatly strengthened this conception of the complex nature of the atmosphere, but in spite of the incontestable facts he presented this truth was not fully recognized until more than a century afterwards.

Boyle extended the knowledge of the physical and chemical constitution of air by the work described in his treatises published between 1672 and 1692. About 1770 Rutherford demon-

[1] Address delivered at the Celebration of the Centenary of the Introduction of Gas as an Illuminant, under the auspices of the American Philosophical Society, The Franklin Institute, The American Chemical Society, and The American Gas Institute, in the hall of The Franklin Institute, Philadelphia, on Friday, April 19, 1912.

strated the existence in the atmosphere of nitrogen and shortly afterwards Priestley separated oxygen from red oxide of mercury, and the significance of this discovery, in relation to the constitution of air, was clearly demonstrated by Lavoisier, who by heating mercury in contact with a measured volume of air showed that about one-fifth of this volume was taken up, with the formation of the red oxide of mercury, and that the remaining four-fifths had all the properties of the "mephitic air," or nitrogen, of Rutherford.

Hydrogen was recognized as an individual gas by Cavendish in 1766 and its name was given to it by Lavoisier.

During the Seventeenth Century some progress was made in determining the identity of carbon dioxide as distinct from atmospheric air and in recognizing its various occurrences as the result of fermentation and combustion and as collected in subterranean and enclosed places at a low level, and as the cause of the sudden deaths known to occur in such places but previously ascribed to the acts of an evil spirit.

Van Helmont is stated by some authorities to have known the identity of the gases from these sources, but according to others these facts were not fully known until nearly the end of the Eighteenth Century. The composition of carbon dioxide was finally determined by Lavoisier.

The existence of fire damp, the name being obtained from the fact that this "damp" or vapor was inflammable, in connection with marshes and coal seams had been known at an earlier date, but Thomas Shirley seems to have been the first Englishman to examine carefully the properties of this important constituent of illuminating gas, now known chemically as methane, and generally as marsh gas, or carburetted hydrogen. In 1667 he published in the *Philosophical Transactions* an account of his investigation in 1659 of the phenomena occurring in a burning spring near Wigan in Lancashire. Shirley demonstrated that the combustible matter was a gas bubbling through the water, which gas he collected from the ground after the water had been diverted into another channel. After this publication many similar observations were made as to the formation of methane by the decomposition of vegetable matter.

One of the earliest observers of the fact that the distillation

of carbonaceous matter yielded a combustible gas was Boyle, who found that when distilled, wood yielded oil, spirit, phlegm (steam), and water. The Reverend John Clayton, in a letter written to Boyle and which, although only published in the *Philosophical Transactions* in 1739, must have been written before Boyle's death in 1691, describes experiments in distilling coal undertaken as a result of seeing gas escaping from a ditch near Wigan which was found to be underlain by coal. He used a retort and obtained first phlegm (steam), then black oil and then a "spirit" which could not be condensed and gradually accumulated until the pressure forced the lute and broke his glasses. The accidental ignition of the escaping gas proved that it was inflammable. By storing some of it in bladders he found that both it and its property of inflammability were permanent.

In 1726 Dr. Stephen Hales distilled wood and coal and noted the toxic effect upon animals of the "air" produced. He states that from Newcastle coal he obtained one-third of its weight of "air," but since this coal, even with improved methods of distillation, yields only one-fifth of its weight of permanent gas some condensable products must have been included in this amount.

In 1767 Dr. Watson published some essays in which he speaks of the giving off of "air" during the distillation of coal.

Even at this comparatively late date, gases were thus spoken of as "air," and although the name "gas" suggested by Van Helmont for these bodies was defined in Macquer's Chemical Dictionary published in 1771 as the "name given by chemists to invisible parts which escape from certain bodies," this name was not used generally until some time after it was adopted by Lavoisier in 1786.

The discovery that the distillation of coal and other carbonaceous substances produced an inflammable and more or less luminous gas was thus made prior to 1690, but it was not until nearly one hundred years later that the idea of using this gas for illuminating purposes was conceived. Then this use seems to have been thought of independently by several persons in different countries at about the same time, and consequently there is a dispute as to who should be accredited as having been the originator of the use of coal gas as an illuminant.

Apparently J. P. Minckelers, a professor in the University of Louvain, in Belgium, in 1784, distilled powdered coal, for the production of inflammable air which he used to fill balloons. In a report advocating the use of coal gas for aeronautical purposes, in which he was particularly interested, he is said to have mentioned the fact that the gas might be purified by being passed through lime water and could then be used for illuminating purposes. It is also claimed that records in the archives of Louvain show that in 1785 Minckelers lighted his lecture room with inflammable air produced by the distillation of coal.

Phillippe Lebon distilled wood and coal in 1786 and in 1799 took out a patent for "a new method of employing fuel with greater utility either for heating or lighting and to obtain certain products therefrom." The apparatus described in this patent was not very practicable and in 1801 he obtained a certificate of additions. In this certificate he calls the apparatus a "thermolampe" and apparently his main idea was to obtain inflammable gas with the object of producing motive power by means of its explosion and little importance was attached to the gas as a means of lighting. For lighting purposes he described a means of consuming the gas inside a glass globe into which gas and air were led by separate pipes and from which the products of combustion escaped by a third pipe. Such a complicated apparatus was not suitable for ordinary use, but his exhibition of lighting by this method, given in Paris in 1802, was written up in glowing terms by the Parisian newspapers and in this way attracted attention all over the Continent of Europe.

The earliest patent taken out in England, in connection with the distillation of coal, was that of Lord Dundonald, for the production of different substances from the distillation of coal, obtained in 1785. His object, however, was the production of tar and while he is said to have lighted the hall of Culross Abbey with crude coal gas in 1787 he apparently did nothing further along the lines of illumination by means of coal gas.

William Murdoch, who is credited in Great Britain and among English speaking countries as being the originator of the use of gas for illuminating purposes, apparently began experimenting along this line at Redruth, Cornwall, in 1792. In that year he distilled coal, peat, wood and other carbonaceous

bodies and, being impressed by the quantities of gas given off during the distillation and the facility with which a brilliant light was produced by this means, he made experiments to determine the relative costs of light so obtained and that obtained from oils and tallow. In 1797 he lighted his own premises in Old Cumnock, Ayrshire, with coal gas. Becoming connected with the firm of Boulton and Watt, quite prominently identified with the development of the steam engine, he lighted with coal gas in 1789 one of the principal buildings of their plant at Soho, Birmingham, and in 1802, in celebration of the Peace of Amiens, the Soho works were strikingly and, for the period, brilliantly illuminated by means of that gas.

Apparently Minckelers and Lebon while working with other objects in view preceded Murdoch in their experiments with, and demonstrations of, illumination by means of coal gas, but the latter was the first to work with illumination as the main object.

Through Lebon, however, the man who probably was the greatest factor in hastening the introduction of the public supply of gas became interested in the subject. This man, Frederick A. Winsor, seeing, in one of the European newspapers, a description of Lebon's exhibition was struck by the possibilities of the process and, going at once to Paris, saw the light and tried to obtain from Lebon information as to the method of producing it. It was, however, impossible for him to pay the high price asked and Winsor left Paris disappointed but determined to find out the causes of such important effects and results.

By the next year he had obtained a certain amount of knowledge on the subject and gave in Brunswick exhibitions of the lighting effect of gas produced by the distillation of wood. At this time he was seized with great force with the idea that England was the most favorable field for the exploitation of the process and, acting promptly on this thought, went to London and there gave, in 1804, at the Lyceum Theatre, lectures and exhibitions on gas lighting. Although working under difficulties, and at first without much success, partly because of his extravagant claims, Winsor persisted in his efforts to promote and finance a National Light and Heat Company, and was finally reported to have obtained nearly £50,000, all of which was expended in the furtherance of his plans. In 1809 he lighted

with gas a portion of one side of Pall Mall, this being the first public street lighted by means of coal gas.

While Winsor was thus working to interest capital in a company to exploit gas lighting over the whole area of Great Britain, attention was also being called to this means of lighting by the lectures of various chemists, and practical applications of the process were being made in various cotton mills by Murdoch, and by Samuel Clegg. Even with the crude apparatus employed, lighting by coal gas was found to be much cheaper and more brilliant than that obtained, according to the general practice of the day, by the use of candles.

In 1809 Winsor and his associates applied to Parliament for a charter for a company to supply gas over the whole of Great Britain. Murdoch, who claimed that priority of invention entitled him to the charter if any were granted, opposed this application and it was denied, but another, made in 1810 by Winsor and his associates, resulted in the passing of an Act authorizing the king to grant, within three years, to the London and Westminster Chartered Gas-Light and Coke Company, a charter covering London, Westminster, Southwark and the adjacent suburbs. The capital was fixed at £200,000 to be raised in full within three years after the granting of the charter, while £100,000 had to be raised before the company could commence operations.

The company finally obtained its charter on April 30, 1812. Its operations were not successful at first, but in 1813 progress began to be made, and by 1815 the company had installed three manufacturing plants and fifteen miles of street mains. Other companies were soon organized and the business of supplying gas progressed so rapidly in Great Britain that by 1829 more than two hundred gas companies had been formed.

The first use of coal gas as an illuminant in the United States is said to have been made in Philadelphia in 1796, but the first definite record of such use in this country is the lighting in 1806 by David Melville of his house in Newport, R. I., with gas made by himself. In 1810 he obtained a patent for "a gas lamp for lighting manufactories, mills, theatres, etc., with hydrogen gas, or inflammable air produced from pit coal," and in 1813 he lighted with gas some mills in the vicinity of Newport.

The first gas company in the United States was organized in Baltimore in 1817 and this was followed by the organization of companies in Boston and New York, but because of the comparative cheapness of other illuminants progress was slow and up to 1830 these were the only cities that had gas works.

I have been unable to find any description of manufacturing apparatus specifically stated to be that employed in the first works of the Chartered Gas Light and Coke Company. It is probable, however, that the apparatus described in "A Practical Treatise on Gas Light," published by Frederick Accum in 1815, as being calculated for lighting towns or large districts of streets and houses, is, even if not exactly the same, very similar to that which was installed in these works, because Accum was the first engineer of the Chartered Company and refers throughout this book to information obtained from Samuel Clegg, who was his successor.

In this apparatus the coal was distilled in cast iron retorts about 15 inches in diameter and 3 or 4 feet long, placed in sets of two in the flues of fireplaces, built under the backs of the retorts, in which coal fires were maintained. The fronts of the retorts opened into a chamber shut off from the operating floor by means of a brick wall through openings in which the work of drawing and charging was done, the coke falling, as it was drawn, through a hole in the bottom of this chamber into a space below the operating floor. The gas leaving the retorts passed through so-called syphon tubes, with a diameter of probably less than 3 inches, into the horizontal condenser, or hydraulic main. The lower end of the syphon tube, or of the dip pipe, was sealed by the accumulation of the liquids condensed from the gas in the hydraulic main until they passed off over the top edge of a partition plate set at a level above that of the bottom of the syphon tube. From this condenser the gas was carried by a take-off pipe to a pipe coil placed in the water in the space between the holder and the tank. After being cooled in this coil, the gas was led into a lime machine while the condensed liquids ran into a tar cistern. In the lime machine the gas was caused to bubble through lime water by which the sulphur compounds were removed. Upon leaving the lime machine the gas was passed through a small washing apparatus placed inside

of the holder, from which it escaped into the interior of the latter.

The holder bell probably had a capacity of about 14,000 cubic feet and was made of light sheet iron fastened to a rectangular frame formed of wooden struts and iron bars, while the tank was apparently made by lining with wrought iron the foundation walls of the building in which the holder was enclosed.

The street mains were made of cast iron spigot and faucet, or bell and spigot, pipes, the joints being made with either iron cement or lead.

Service pipes up to a diameter of 1¼ inches were made of tubes of welded wrought iron in 3-foot lengths with wrought iron fittings and screwed joints.

For house piping tubing made either of sheet iron brazed, of lead or of copper with lap-over joints was used. Copper with brass fittings was recommended by Peckston for interior work, with wrought iron tubing for pipe exposed to the weather. The burners were either cockspur, consisting of three round jets, a single round jet, batswing or Argand.

In the 1819 edition of Peckston's "Theory and Practice of Gas Lighting" it is stated that the general mode of charging customers for light was at a certain sum per annum for burners of given dimensions burning from sunset until a stipulated hour, but that this was not satisfactory and that meters for measuring the actual amount of gas used were being gradually introduced, a suitable meter having been brought out in 1817.

In a modern coal gas plant the retorts in which the coal is carbonized are made of clay, are D-shaped with a height of about 16 inches, a width of 24 to 28 inches and a length of 9 to 10 feet for what are known as single retorts, or from 11 to 20 feet for what are known as through retorts. They are set in groups of from six to twelve, each group or bench being heated by means of a generator furnace equipped with recuperators. As a rule the long axis of the retort is horizontal, but that of through retorts is sometimes inclined about 32° from the horizontal and during the last five years the practice of having this axis vertical has been quite largely adopted. In smaller works the coal is charged into, and the coke drawn from, the retorts by hand, but in larger works these operations are performed by

machinery. The stand, bridge and dip pipes, through which the gas passes from the retorts to the hydraulic main, have a diameter of 7 or 8 inches. Except for details of construction adopted to insure the sealing of the dip pipes in ammoniacal liquor the hydraulic main remains much the same as in the early works.

The amount of apparatus between the hydraulic main and the holder has been greatly increased from that in the original plants, in order that the removal of tar, the cooling of the gas and the removal of ammonia and of the sulphur compounds may all be efficiently effected.

In the United States the first piece of this apparatus is often a primary condenser, or cooling vessel, employing air as the cooling medium. Either following this condenser or being itself first in the series is an exhauster or gas pump, which relieves the retorts of the pressure thrown by the holders and the friction developed as the gas passes through the apparatus between the exhauster and the holder. From the exhauster the gas passes into a frictional tar extractor, then to the secondary condensers, which are usually water cooled, and then to the washers or scrubbers for the removal of ammonia by solution in water, a washer being a vessel in which the gas is caused to pass through water in small bubbles, while a scrubber is one in which the gas passes in thin streams over surfaces kept wet with water. Leaving the scrubbers the gas goes to the purifiers, where it is freed from sulphuretted hydrogen by means of the chemical affinity between this substance and the oxide of iron which forms the active portion of the purifying material customarily used. After passing the purifiers the gas is measured by large wet meters and then passes to the holders, which, except in the smallest plants, are made with more than one lift and for large plants vary in capacity from 1,000,000 cubic feet to the 15,000,000 cubic feet of the largest holder in the world, that at the works of the Astoria (L. I.) Light, Heat and Power Company.

In some of the larger works rotary scrubbers for the removal of cyanogen and naphthalene are also provided.

The change from the simple plant described in Accum's Treatise to the more complete modern one was made gradually as knowledge was gained concerning the principles involved in the distillation of coal and the subsequent treatment of the

volatile products of such distillation. These principles are treated of later.

About 1850 clay retorts began to replace iron ones because of their ability to withstand a much higher temperature, and so make possible a much larger production of gas from a given quantity of coal. The temperature to which the retorts could be heated was increased and economy of fuel obtained by improvements in the design of the furnaces and in the method of setting the retorts. The greatest advance, however, in securing both intensity of heat and economy of fuel came with the introduction of generator firing and the preheating of the air used for combustion by means of the heat contained in the waste gases passing to the chimney. While one of the earliest experiments with gaseous firing for heating retorts was made in 1862 when a Siemens regenerative furnace was used for the purpose at one of the gas works in London, this method of heating was developed on the continent of Europe. The Siemens furnace was too elaborate for general use, but simpler generators and recuperators were soon devised and by 1874 had been adopted in about twenty works. After that time the progress was rapid on the Continent, but up to 1878 there was practically no gaseous firing in either England or the United States. In that year Dieterich furnaces were installed in one of the gas works in Baltimore and experiments, apparently not very successful, were made in several places with other furnaces, but success was obtained in the early eighties and after 1885 the use of generator furnaces and recuperators became general in the larger coal gas plants.

The exhauster, first introduced in 1841, came into general use at the same time as clay retorts. Its use is required because a high pressure on the hydraulic main coupled with the bubbling of the gas through the hydraulic seal on the dip pipes produces in the retorts great fluctuations in pressure and a consequent pulsation of the gas passing off from the coal, which increases very greatly the extent of its contact with the hot walls of the retorts and the destructive breaking down of valuable hydrocarbons by reason of this contact.

The change from the condensing coil placed in the gas holder tank to the form consisting of vertical pipes connected at the top

in pairs by return bends and at the bottom into a cast iron box with suitable partitions came before 1841. This form, while still commonly used in Great Britain, has been superseded in the United States by condensers in which the gas passes through an enclosed space traversed by tubes or pipes, the cooling medium being either water or air flowing through these tubes.

It is uncertain when washers and scrubbers were first introduced for the purpose of absorbing ammonia. Washers, apparently placed ahead of the condensers, were used at some works before 1841, but they were tar extractors rather than ammonia extractors. By 1853 tower scrubbers filled with coke were being used but also seem to have been intended more for the removal of tar than for that of ammonia. By 1868, however, the use of tower scrubbers for the removal of ammonia from the gas before it entered the purifiers seems to have been thoroughly established. Rotary scrubbers were introduced shortly after 1880 and have been adopted in the larger plants.

The change from wet to dry methods for the removal of sulphuretted hydrogen and other sulphur compounds, advocated as early as 1817, had not become general in 1841, but the use of dry lime was generally adopted soon after that year and from 1850 on the use of oxide of iron as a purifying material became quite common and in recent years it has been almost the only material employed for this purpose.

The use of station meters began soon after 1815.

The increase in the amount of gas sold and the difficulty of securing ground space in the crowded neighborhoods in which the early gas works were built gradually led to the use of holders of more than one lift and the capabilities of the older methods of guiding holders, that is of providing against their being upset, were soon outgrown. At first holders were guided either by the sliding along a central post of an open pipe with its lower end sealed in water or by means of chains attached at different points around the circumference of the crown and led over grooved wheels to be fastened to a single weight which descended as the holder was raised. Later the guiding was by means of wheels or rollers fastened at points equally distant around the outer edge of the crown and the bottom curb and working against rails or plates attached to the tank wall and to

columns, each composed at first either of a single cast iron cylinder, or in some cases of groups of cast iron columns joined together by struts, and later of a single wrought iron cylinder, the columns whatever their form of construction being joined at the top by means of wrought iron girders. The latest style of guide framing, which came in use with the adoption of holders of more than two lifts, consists of structural steel columns joined to each other by several series of horizontal struts and diagonal ties in such a way that the whole frame may be considered as forming a rigid cylindrical cantilever.

At about the same time that the modern system of guide framing was adopted the use of steel tanks built largely above ground in place of the brick tanks built below the level of the ground also began to become general in the United States.

Until recently the comparatively small retorts employed in gas works formed the sole source of coal gas, but now the by-product, or retort, coke oven used in the manufacture of coke also affords a supply of such gas for illuminating purposes. When first introduced all the gas produced by these ovens was consumed in the plant itself, but shortly after 1896 the sale of surplus gas for illuminating and heating purposes was begun in Glassport, Pa., and in 1899 this sale on a large scale was entered into by the New England Gas and Coke Company with a plant at Everett, Mass., supplying gas to Boston and its suburbs. Since that time other plants have entered this field until there are now eleven coke oven plants selling illuminating gas in the United States.

When the surplus gas is to be sold two separate sets of hydraulic mains and condensing and scrubbing apparatus are provided, one handling the rich gas made during the early, and the other the poorer gas made during the latter part of the charge. The rich gas is distributed, while the poorer gas, after being freed from ammonia, tar and benzol, is used for heating the ovens. In one or two plants the ovens are heated with producer gas made from part of the coke and all the coal gas is sold.

Apart from the use of retort ovens, instead of retorts, the treatment in a coke oven plant of the gas which is to be sold does not differ materially from that in an ordinary coal gas plant.

The advantages claimed for coke ovens as producers of coal

gas are low labor costs, because of the large weights of coal used in one charge, and the production of a quality of coke which in many localities commands a better market than does ordinary gas coke.

While in Europe the carbonization of coal furnished up to about 1894 practically the sole source of illuminating gas and is still by far the largest source of such gas, in the United States it is second in this field to carburetted water gas. The latter gas is produced by mixing with non-luminous water gas a sufficient amount of oil gas to give the mixture the desired illuminating value.

The decomposition of steam by means of highly heated carbon, with the formation of water gas, was known before the coming into use of coal gas and was experimented upon by Fontana in 1780. After the introduction of coal gas efforts to carburet water gas were begun and in 1847 a patent was taken out in England by Stephen White for the production of a combined coal and water gas. The process covered by this patent was widely discussed by gas engineers of that time and was favorably regarded by some of them, but it proved to be incapable of control and therefore to give very variable results and was not a commercial success. Other processes for the production of carburetted water gas were presented but none of them were successful until in the early seventies T. S. C. Lowe devised in this country the apparatus which, although greatly modified and much improved by other men, still bears his name. The success of this apparatus is due to the principle, first employed in it, of the internal heating of the vessels required for the manufacture of the oil gas needed to carburet water gas, by the combustion in them of the combustible portion of the producer gas formed while the fuel in the water gas generator is being brought up to the temperature necessary for the decomposition of steam.

The Lowe apparatus, in which the water gas and oil gas are made practically in one operation, while the conditions suitable for the manufacture of each can be separately obtained and controlled, in connection with the supply of cheap and suitable carburetting materials afforded by the large production of petroleum and its distillates, made the manufacture of carburetted water gas commercially practicable and economical in the United States

and after the installation of the first apparatus in Pennsylvania in 1873 it was rapidly adopted until at the present time it furnishes slightly more than two-thirds of the total amount of illuminating gas made and sold in this country.

The generating apparatus employed in the manufacture of this gas consists of three suitably connected cylindrical vessels constructed of steel plates and lined with fire-clay blocks. The first vessel, called the generator, contains the fuel and furnishes both the producer gas and the water gas required. The other two vessels, in which the oil gas is made, are called respectively the carburetter and superheater and are filled with fire-brick piled in rows from 2 to 3 inches apart, the rows in one tier being at right angles to those in the tiers next above and below. The necessary blast, steam and oil connections are provided and at the top of the superheater there is a take-off pipe with its lower end sealed in water in an auxiliary vessel and having an opening to the atmosphere that can be closed by a self-sealing lid.

A fire having been started in the generator it is gradually filled with coal or coke and this fuel is brought up to a state of incandescence by air blown in under pressure. Because of the deep fuel bed producer gas is formed, the combustion of which in the carburetter and superheater heats the checker brick in these vessels to the temperature required for the gasification of oil. When the proper temperature has been reached in all three vessels the blast is shut off, and the opening into the air from the take-off on the superheater is closed. Steam is admitted to the generator and passing through the fire is decomposed by the combination of its oxygen with the hot carbon and the gas thus formed, consisting principally of carbon monoxide and hydrogen, passes to the carburetter. Oil sprayed in at the top of this vessel is vaporized by the heat and the vapors travel with the water gas through the carburetter and superheater, being converted during this travel into a permanent oil gas. The carburetted water gas thus produced must be cooled and purified as in the case of coal gas except that since it contains practically no ammonia it is not necessary to pass it through apparatus for the removal of that substance.

In the larger gas works the manufacture of both coal and carburetted water gas in conjunction is advantageous. The fluctuations in demand and the seasonal peak requirements can

be cared for much more economically with a carburetted water gas plant than with a coal gas one, because of the smaller investment required by the former for a given generating capacity and the greater ease and economy with which it can be put into and taken out of action. In many cases it has been found that even when the cost of carburetted water gas is greater, the cos of a properly proportioned mixture of the two will be less than the average cost of coal gas alone.

A combination plant has also the advantage of giving the company possessing it a better control of the market for coke, the main residual of coal gas manufacture, and placing it in a position to take advantage of fluctuations in the prices of coal and of petroleum because of its ability to vary the amount of gas made from either of these raw materials. Owing to these advantages of the combination plant almost all of the companies in the United States manufacturing more than 50,000,000 cubic feet of gas per year make both coal gas and carburetted water gas.

For many years gas had been made by the distillation, in retorts, of petroleum and other hydrocarbon oils, such as the Scotch shale oils, but this gas was used only for such special purposes as the lighting of railway cars or the enrichment of coal gas, the amount so used forming a small proportion of the total amount of gas distributed. In California, however, the high price of all carbonaceous materials except petroleum led about 1900 to experiments which resulted in the development of a process by means of which is made, from crude petroleum, or one of its heavier distillates, as the sole raw material, a gas very similar in its composition to coal gas but very different from that produced by distilling oil in retorts.

The generating apparatus employed in making this gas is similar to that employed in the manufacture of carburetted water gas and consists of two cylindrical steel shells lined with fire-clay blocks and filled with checker brick. The heat required for the gasification of the oil is obtained by the combustion, by means of air supplied under pressure at suitable points, of oil sprayed in through burners placed around the circumference of the primary generator near its top. When the proper temperature has been reached the blast valves and the stack valve at the top

of the secondary generator are closed, the supply of oil through the heating burners is stopped and oil is sprayed in through other burners at the top of the primary generator and also at either the bottom or the top of the secondary generator. Because of the large amount of contact with the highly heated surfaces of the checker brick to which the oil vapors and gas first produced are exposed, from 20 to 25 pounds of carbon in the form of lampblack are set free per 1,000 cubic feet of gas made and the handling and disposal of the carbon, which is used as boiler fuel or as the generator fuel for the manufacture of carburetted water gas to be mixed with the oil gas and, in some places, is made into briquettes and sold for fuel purposes, is a problem connected with this process.

This method of manufacturing gas requires the use of from 10 to 14 gallons of oil per 1,000 cubic feet as compared with about 4 to 5 gallons of oil per 1,000 cubic feet of carburetted water gas and so is economical only where the cost of the extra 6 to 9 gallons of oil is less than that of the 30 to 50 pounds of coal which would be required for making the water gas portion of carburetted water gas.

Another source of illuminating gas which has been availed of to some extent both in the United States and in Germany is the distillation of wood.

Wood gas was made in the Philadelphia Gas Works continuously from 1854 to 1864 and during several years of this period formed about 5 per cent. of the total amount of gas made. It was also the only gas that could be manufactured in several southern cities during the Civil War. In these instances it was made as a substitute for coal gas, the wood being distilled in retorts similar to those used for distilling coal.

At the works of the Mutual Gas Light Company in New York City wood gas was made from 1879 to 1884 as a substitute for water gas. The wood was distilled in L-shaped retorts so charged that gas given off in one part of the retort passed through a mass of heated charcoal in another part. This produced a non-luminous gas which was carburetted with oil gas. A similar retort and method of operation is used in the Riché process recently patented in France, which, however, is claimed to produce gas of a fair illuminating value.

At the present time wood gas is being distributed in a small town in Washington, but apart from special local conditions cannot be produced as cheaply as other gases.

As a result of a wide-spread belief that there was a market for a fuel gas of lower calorific value and cheaper cost than ordinary illuminating gas, attempts were made, between the years 1880 and 1896, in twenty-seven different towns in the United States to distribute either blue water gas or water gas partially enriched with oil gas to give it greater calorific value. The calorific value of the gas so distributed ranged from about 300 B.t.u. per cubic foot for the blue water gas to as high as 450 B.t.u. for the partially enriched gas. Many of these attempts were made after the introduction of incandescent gas lights so that the gas could be used, and its use was advocated, for lighting as well as for fuel purposes, but in no instance was the effort to sell such a gas commercially successful and the companies undertaking it soon went out of business or turned to the manufacture of illuminating gas. This result was reached even in the few instances where this fuel gas, being the only gas supplied in the locality, did not have to compete with any other form of gas.

These attempts to distribute fuel gas of a comparatively low calorific value failed because the cost of a given number of heat units could not be made sufficiently lower than that of the same number derived from a gas of a higher heating and illuminating value to counterbalance the disadvantages of having to consume larger quantities of gas and take a much longer time to do the same amount of work.

No attempt to distribute gas of low calorific value has been made in the United States since 1897, but there is in England a company which was organized about six or seven years ago for the purpose of supplying to a populous manufacturing district "Mond gas" for use by large consumers for power and fuel purposes. "Mond gas" is a producer gas made by passing through a bed of incandescent fuel air mixed with as much steam as it is possible to use without reducing the temperature of the fire below the point at which the decomposition of the steam with the formation of water gas will take place. It contains about 40 per cent. of combustible matter mixed with a total of 60 per cent. of nitrogen and carbon dioxide and has a calorific

value of about 156 B.t.u. per cubic foot. The use of the large amount of steam leads to the formation of large quantities of ammonia and the recovery and sale as a residual of this ammonia is one of the principal features of the process, which can only be used on a large scale, and it was thought that the recovery of the ammonia and the large scale working would make it possible to sell the gas at a price at which it would be attractive to users of fuel and at the same time pay a good return on the investment. As late as two years ago, however, the annual report of the company showed that the operating expenses had been barely met and that nothing was being earned upon the investment. The low cost of manufacture and the comparatively small investment in manufacturing apparatus seem to make it impossible to meet the relatively larger distribution costs and investment and still compete with isolated plants.

Analyses of some of the various kinds of gases mentioned above are given in the appendix.

The problem of the destructive distillation of carbonaceous bodies for the production of gas for illuminating and heating purposes has two distinct divisions, the first being the proper application of heat to the material in order to secure the greatest possible quantity of gaseous products of good quality and the second being the proper treatment of the volatile portions of the products of distillation in order to conserve in the gas the greatest possible amount of light and heat giving bodies.

The determination of what constitutes the best possible heat treatment to apply to the raw material is rendered difficult by the complex nature of the reactions which take place when coal or any other material consisting largely of carbon and hydrogen is heated to a high temperature without any access of air.

A clear knowledge of the character of, and the effect of heat upon, the substance called hydrocarbons is requisite for the successful solution of the problem. The hydrocarbons with which the manufacturer of coal gas is concerned belong to five groups, each group consisting of a number of substances which resemble each other in composition but have varying densities and boiling points. These groups are the paraffins with a composition represented by the formula C_nH_{2n+2}; the olefins with a formula of C_nH_{2n}; the acetylenes with a formula of C_nH_{2n-2}; the benzene

series with a formula of C_nH_{2n-6}, and naphthalene. In the paraffin group the affinities of the carbon atoms are fully met by the hydrogen atoms and consequently they are known as saturated hydrocarbons and are more inert than the members of the other groups in which the affinity of the carbon is not so fully satisfied by the hydrogen contained in them. In each group the bodies containing the smaller number of carbon atoms in the molecule have the lower densities and boiling points.

The lower members of the paraffin, olefin and acetylene series are all gases, while the higher members of these series and all of the benzene series are liquids, and naphthalene is a solid, at ordinary temperatures and pressures. Certain amounts of the vapors given off from these liquids and from naphthalene can be carried, however, by a gas under ordinary conditions.

The exposure of hydrocarbons to heat produces changes in composition which in general consist of a splitting off of hydrogen atoms and result in the formation of hydrogen and hydrocarbons simpler than the ones acted upon. The exact nature of these changes depends, however, upon the character of the hydrocarbons and the nature and intensity of the heat to which they are exposed.

It is probable that the first products of the heat action are complex hydrocarbons, largely paraffins of high density and boiling point, and that, during their passage through the retort, these by further exposure to heat are broken down into hydrogen and simpler hydrocarbons. The primary products are either liquids or vapors at ordinary temperatures and consequently little gas would be formed if they were permitted to remain in their original condition. On the other hand excessive exposure to heat, and especially to contact with highly heated surfaces, produces secondary reactions resulting finally in the formation of a gas consisting largely of hydrogen through which are diffused hydrocarbon vapors, most of which will be condensed at temperatures and pressures frequently met with during the distribution of gas, and the setting free of carbon which causes much trouble in the generating apparatus. The problem, therefore, is so to adjust the conditions under which the secondary reactions occur as to secure the proper amount of breaking down while avoiding anything in excess of this amount.

Starting with a given amount of carbon and hydrogen in the

raw material the heat treatment to which the material should be subjected to obtain any desired character of gas depends upon the following principles: Radiant heat tends to split up complex paraffins into simpler paraffins and olefins and if the exposure to such heat is continued for a sufficient length of time at a sufficiently high temperature the final result is the decomposition of the complex bodies into methane, the lowest of the paraffin series which is not affected by radiant heat, and several of the lower members of the olefin series. On the other hand, heat communicated by surface contact tends to produce from a paraffin, hydrogen and hydrocarbons of the benzene group. In each case the action is accelerated and intensified by increase in temperature of the radiant, or contact, surfaces.

The mixture of olefins and methane has a larger volume and a higher illuminating value than the original paraffins, but is exceeded in both respects by the mixture of hydrogen and benzene vapor. The latter mixture will not contain, however, sufficient hydrogen or other permanent gas to carry the vapor at the ordinary temperatures unless some of the carbon originally present is set free and lost as far as the resulting gas is concerned.

Therefore when a hydrocarbon gas is to be used alone as in the case of the manufacture of coal gas, or is even to be used to enrich another hydrocarbon gas, and illuminating or calorific value is of importance, the gas and vapors escaping from the coal or other material being distilled should be exposed to the action of radiant heat at not too high a temperature but should be protected from contact with highly heated surfaces. When, as in the case of the manufacture of carburetted water gas, the hydrocarbon gas is to be used for the enrichment of a mixture of simple gases, which can carry comparatively large amounts of hydrocarbon vapors, contact with heated surfaces produces good results, especially when the hydrocarbons are exposed to such heat action while being carried by the simple gas, since the presence of that gas arrests the action before it reaches the point at which carbon is set free.

There is no such protecting and carrying gas present in the manufacture of oil gas as carried on along the Pacific Coast and consequently in this process the contact of the hydrocarbons with highly heated surfaces results in the setting free of sufficient

carbon to form the hydrogen required to protect the remaining methane and uncombined olefins and carry the vapors of the benzene group. The setting free of a certain amount of carbon and its recovery in the form of lampblack is therefore an inherent feature of this process whatever the character of the oil used as the raw material.

Even when no importance is attached to illuminating value the calorific value of the gas derived from a given quantity of material will be greater the smaller the amount of carbon set free and since methane, one of the most important constituents of coal gas from the calorific standpoint, is not affected by radiant heat but is decomposed by contact with hot surfaces, especially at temperatures above 600° C. (1112° F.) it is still important, when making a hydrocarbon gas by itself, to subject the gas only to the action of radiant heat and avoid as far as possible contact with highly heated surfaces.

Practice in carbonization in gas works had gradually come to agree with these principles even before they were thoroughly understood. Early in the manufacture of coal gas it was recognized that better results as far as the production of gas was concerned were obtained when coal was carbonized in thin layers and at comparatively high temperatures. In working along these lines, however, the portion of the walls of the retort above the charge of coal afforded a large amount of hot surface in proportion to the amount of gas being made and as the temperature at which carbonization was carried on was increased much trouble was experienced from the free carbon produced by the action of this heated surface. To avoid this trouble it was found necessary to increase the weight of the charges placed in a given size of retort and lengthen the time during which the carbonization of the charge lasted until finally as a result of experience with intermittently charged vertical retorts it has become the practice to fill horizontal retorts as completely as possible and make the duration of the period of carbonization sufficiently long to drive all of the gas out of these large charges. The gas, however, is still exposed to contact with hot coke during at least portions of the long period of carbonization and while the use of these large charges has increased both the quantity and quality of the gas produced from a given weight of coal

the results obtained from them are probably not as good as could be obtained by the carbonization of coal in smaller charges with the proper exposure of the gas to radiant heat of a low intensity. The use of large charges reduces labor costs, but it is questionable whether a point is not soon reached at which any saving in this direction is more than overcome by a loss in the quantity and quality of the gas made, and it is possible that experiments with horizontal retorts, of much smaller dimensions than those now used, completely filled with coal would show sufficiently better gas results to compensate for increased labor costs, but the continuously operated vertical retort, into which coal is introduced in small amounts at intervals of a few minutes and in which it is possible to regulate very closely the extent to which the gas is subjected to radiant heat, seems to offer the best means of solving the problem of securing the proper heat treatment during the distillation of coal.

Even when the best conditions of heat treatment are attained the gas issuing from the retorts or other generating apparatus is a mechanical mixture, the principal constituents of which are hydrogen, methane and more complex hydrocarbons, some of the latter being vapors, with smaller amounts of carbon dioxide and various impurities, and the second portion of the problem of the manufacture of a hydrocarbon gas is to so treat this mixture that, when the cooling from the high temperature at which it leaves the retort to atmospheric temperatures and the removal of the impurities has been completed, it will retain as large an amount of these hydrocarbon vapors as it is possible to carry to the consumer. The problem of doing this is rendered difficult by the fact that being the vapors of liquids mutually soluble in each other the combined tension of these vapors is much below the sum of the vapor tensions of each and when one of high boiling point is condensed into the liquid form it will carry down with it some of the others whose boiling points are such that, if left to themselves, they could be retained in the gas. It is, therefore, necessary to effect the cooling of the gas in such a way that the condensing out of the vapors which it is impossible to retain in the gas shall be accompanied by as small a loss as possible of those vapors which can be retained. The problem is further complicated by the fact that the employment of the

best method of achieving this result is apt with coal gas to lead to trouble in the distribution system from the saturation of the gas with naphthalene, a heavy vapor which condenses directly to the solid form, unaccompanied by other vapors which condensing simultaneously into liquids would dissolve the naphthalene. It is therefore necessary to compromise and suffer a small loss in one direction in order to avoid trouble in another. On the whole, however, the best treatment consists in the removal of the tar, formed by the condensation of the heavier vapors, while the gas is still at a temperature of above 100° F., and a subsequent gradual cooling of the gas to atmospheric temperatures, the condensed liquids formed at different temperatures being removed before any great further drop in temperature has taken place.

When the gas has reached atmospheric temperature it is necessary to remove the ammonia which has not been absorbed by the condensation during the cooling of the gas, of the aqueous vapor which it contained when it left the hydraulic main. This removal is effected by the use of water. After the removal of ammonia the gas must be treated for the removal of sulphuretted hydrogen and the reduction of the amount of other sulphur compounds if this latter amount is excessive. The purifying material commonly used in the United States for the purpose has as its active agent hydrated sesqui-oxide of iron. This combines with sulphuretted hydrogen to form sulphide of iron, which upon exposure to the atmosphere is oxidized with the re-formation of the hydrated ferric oxide and the setting free of sulphur. The efficiency of this portion of the process increases with rise in temperature and in many gas works the gas is heated to a temperature of about 100° F. at the inlet of the purifiers.

The purifiers complete the chemical and physical treatment of the gas, which leaves them fit for distribution, but for economical reasons it is measured and then passed into storage holders before being sent out.

In the early years of the industry the treatment given the raw material and the resulting volatile products was largely governed by rule-of-thumb, but in recent years all the manufacturing steps have been studied scientifically and great progress has been made both in knowledge as to principles and in the practical application of this knowledge. Much remains still to

be investigated and there is no reason to doubt that the processes now employed will be improved as time goes on and that the debt of humanity to the gas industry, accumulated during the first century of its existence, will be largely increased during the second.

APPENDIX.

	Coal gas.	Carburetted water gas.	Water gas.	Crude oil gas.	Oak wood gas.
Candle-power	16.7	24.5	—	19.7	26.0
Specific gravity	0.430	0.625	0.53	0.482	0.580
B. t. u. per cubic foot					
Observed	—	626.8	316.8	679.9	—
Calculated	659.7	626.7	302.2	—	—

ANALYSIS.

		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Illuminants—unfixed	C_nH_n	0.80	0.6	—	7.01	6.46
fixed	C_nH_m	4.00	11.4	—		
Carbon monoxide	CO	8.20	31.3	42.8	9.21	26.11
Hydrogen	H_2	45.20	36.1	50.3	39.78	30.44
Marsh gas	CH_4	37.40	12.6	0.4	34.64	33.12
Ethane	C_2H_6	0.70	2.3	—	—	—
Carbon dioxide	CO_2	1.60	3.0	3.0	2.62	0.48
Oxygen	O_2	0.30	0.4	0.4	0.16	—
Nitrogen	N_2	1.80	2.3	3.1	6.58	3.39
		100.00	100.0	100.0	100.00	100.00

Peat-gas Plant. ANON. (*Elect. Rev.*, lxix, 1017.)—This is a producer-gas plant, made by Messrs. Crossley Brothers, installed in a factory at Portadown, Ireland, for power purposes. It consists of two producers, each of 200-horsepower capacity, with a coke scrubber, centrifugal tar extractor, sawdust scrubber (or filter), exhauster fan, and expansion box. It is worked by suction produced by the high-speed fan exhauster, which also delivers the gas to a gas-holder. The feeding hoppers on the producers are larger than those usual with coal fuel, but the gas is similar in constitution to suction gas from Welsh anthracite, though with less hydrogen; its thermal value is 140 B.t.u.'s per cubic foot. The peat has about 26 per cent. moisture as charged into the producer, but in exceptionally dry seasons it is as low as 19 per cent. With an average load of 275 horsepower the fuel cost—allowing 35 s. per week for tar sold—is £4 5 s. ($21), as against £13 16 s. 3 d. ($69) per week for anthracite, which was used in the Mond plant replaced by this peat-gas installation. The tar from the peat amounts to about 5 per cent. of the weight of fuel used. Analysis shows it to contain a small amount of paraffin wax and a considerable proportion of heavy oils distilling above 270° C.

THE ELECTRO-PNEUMATIC BRAKE SYSTEM FOR STEAM ROAD SERVICE.[1]

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THIS equipment was designed for electrically operated trains, in which all vehicles are equipped with a compressor, or have a main reservoir supply line. Since all the braking power for service can be obtained from a 70 ℔ brake pipe pressure, it is obvious that the high main reservoir air can be utilized for emergency applications, thus making it unnecessary to increase the brake pipe pressure. To this end, the equipment described immediately hereinafter was developed, being perfected to a greater degree than any equipment heretofore designed. The service and emergency brakes are separated; that is to say, the mechanism and reservoirs controlling the emergency operation are different from those controlling the service operation. About all that is required of the service parts in emergency is to close and open the exhaust ports.

It will be seen from the above that two valuable features, not realized in any previous brake equipment, are attained: First, a very large and inexhaustible supply of air for the emergency brake; and, second, a high-pressure brake, without the necessity of increasing either the brake pipe or main reservoir pressure beyond that now carried by the most ordinary or least efficient brake equipment.

From these two features greater safety is secured, due to the increased braking power and very economical operation, since a compressor of about one-half the capacity formerly required may be used.

Another valuable feature of this equipment is that it is so designed that, if desired, cars can be equipped with only the service pneumatic portion. Then, as the service conditions

[1] Continued from page 155.

change, the quick action portion can be added. Then, for other conditions, the high-pressure emergency feature can be added; then the electro-pneumatic service feature may be added; and, for still more important operation, the electric quick action or emergency features can be added, and all this accomplished without discarding any parts.

This equipment, then, briefly stated, consists of the most improved form of pneumatic service and emergency brake, interlocked with electric control of both service and emergency operations.

The important features in detail are: Full protection against complete loss of the brake, due to failure of any part of the system; maximum and predetermined flexibility for service operation; certain and uniform action; predetermined and maximum practicable difference between service and emergency braking powers; instantaneous quick action; complete separation of service and emergency features, both electric and pneumatic; full emergency pressure obtainable at will, even after a full service application; automatic emergency when predetermined brake pipe reduction is made after equalization, or when brake pipe pressure is reduced below a predetermined danger point, due to leakage or other causes; brake cylinder pressure maintained in emergency; improved graduated release features.

The quick action feature of the equipment is different from previous types of brake apparatus, in that brake pipe air is vented to the atmosphere in emergency operation, instead of to the brake cylinder.

The quick recharge and graduated release features not only add to the flexibility of control, but also insure an additional factor of safety, because the inherent operation of the apparatus is such that the brakes must be either set or the system recharged ready for prompt application when desired.

Protection against complete loss of brake is insured, since the pneumatic and electric systems are operatively interlocked. While the brakes are being controlled electrically (which is the normal condition), the pneumatic control is held in reserve, without its efficiency in any way being impaired by electrical operation. Consequently, if the electric service control should partially fail from any cause, all the brakes would apply automat-

ically and without the necessity of the motorman even becoming aware of the fact. Therefore, the difference between the electric and pneumatic action is merely with respect to promptness and uniformity on the train as a whole.

The brake application is brought about electrically in the same manner as when applied pneumatically, *i.e.*, by making a brake pipe reduction, in response to which the operation of the mechanism directly controlling the flow of air from the auxiliary reservoir to the brake cylinder takes place in the same manner and produces the same results in either case. The only difference is that in making the pneumatic service application the brake pipe reduction occurs at one point—the brake valve—while when operating electrically, the service application magnet valves make the brake pipe reduction at the proper rate, and simultaneously on each car in the train, which insures a brake application throughout the train in the shortest possible time. The failure of one or more of the application magnets to operate results simply in the brake pipe reduction taking place through the other service magnet valves, or possibly through the brake valve as well. Electric control also adds to the flexibility of the operation.

Certainty and uniformity of service action, combined with protection against undesired operation, due to the inevitable fluctuations of the brake pipe pressure or small brake pipe reductions, is provided for in the design of the valve, which insures that the equalizing piston will move so as to close the feed groove on the slightest brake pipe reduction, and then the necessary and proper differential must be built up to move the parts to service position, as the brake pipe reduction is continued.

The maximum difference between service and emergency braking powers is possible, since the maximum cylinder pressure in service is determined by the equalization of the auxiliary reservoir and brake cylinder, whereas the emergency brake cylinder pressure is determined by the pressure in the main reservoir, and not by the auxiliary reservoir pressure, thus giving the effect of a high-speed brake with low-brake pipe pressure carried.

Instantaneous quick action is obtained whether originating at the brake valve or at any point in the train. This follows from the fact that the emergency action is subject to the movement

of the emergency switch on each car, as well as the brake valve movement. The same protection exists for emergency as for service application, viz., that if the electric emergency feature of the equipment becomes inoperative for any reason, the pneumatic emergency operation occurs automatically, and, as this function cannot be impaired any more than the emergency action of the ordinary quick-action automatic brake, it follows that absolute protection against complete loss of the brake is insured.

The complete separation of the service and emergency functions permits the necessary flexibility for service applications without impairing in the least the emergency features of the equipment, and eliminates the possibility of undesired quick action in so far as the triple valve service action is concerned. It also insures the obtaining of emergency at any time, no matter what service application has been previously made.

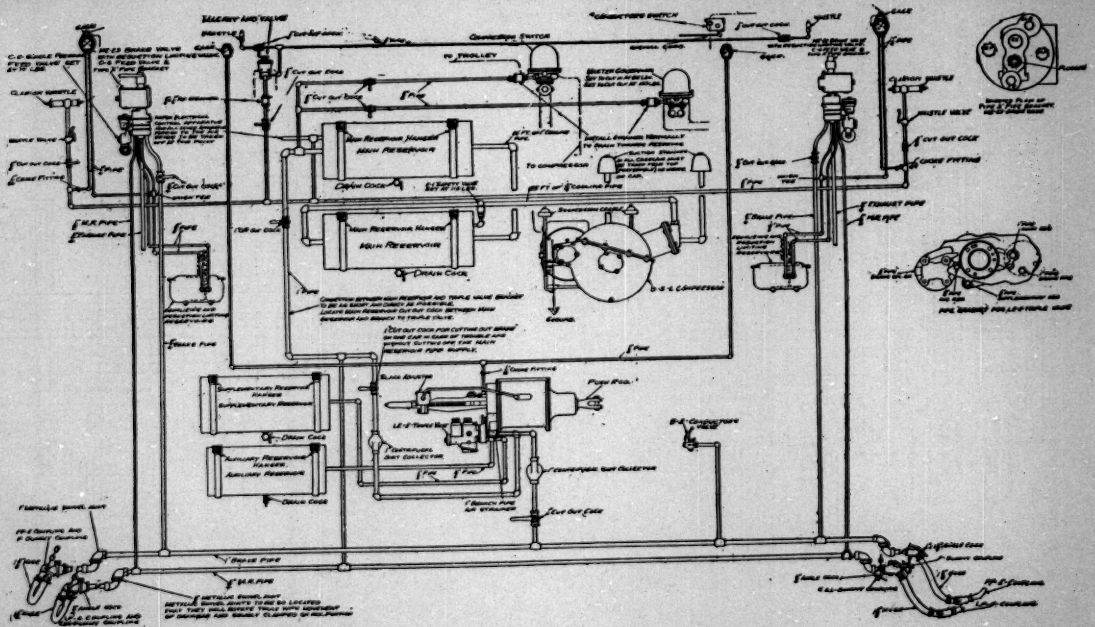
Fig. 15 shows the piping diagram of the equipment, which pneumatically consists of the usual combination of auxiliary reservoir, triple valve, and brake cylinder, with the addition of a supplementary reservoir. The functions of the auxiliary reservoir and brake cylinder are similar to those of the ordinary quick-action automatic brake. The supplementary reservoir assists in obtaining graduated release and the quick recharge of the brake.

Fig. 16 shows the wiring diagram. Electrically, the equipment comprises the usual application and release magnets, with their attached valves, controlling the electric service application and release of the brakes. In addition to these, there is a third magnet, the emergency application magnet, with its valve, controlling the operation of the emergency parts of the triple valve. The emergency switch might be called the connecting link between the pneumatic and electric emergency features of the equipment. It serves as a circuit closer to start the electric transmission of quick action throughout the train, when originating pneumatically.

The real distinct and novel features of this equipment are embodied in the brake valve and triple valve.

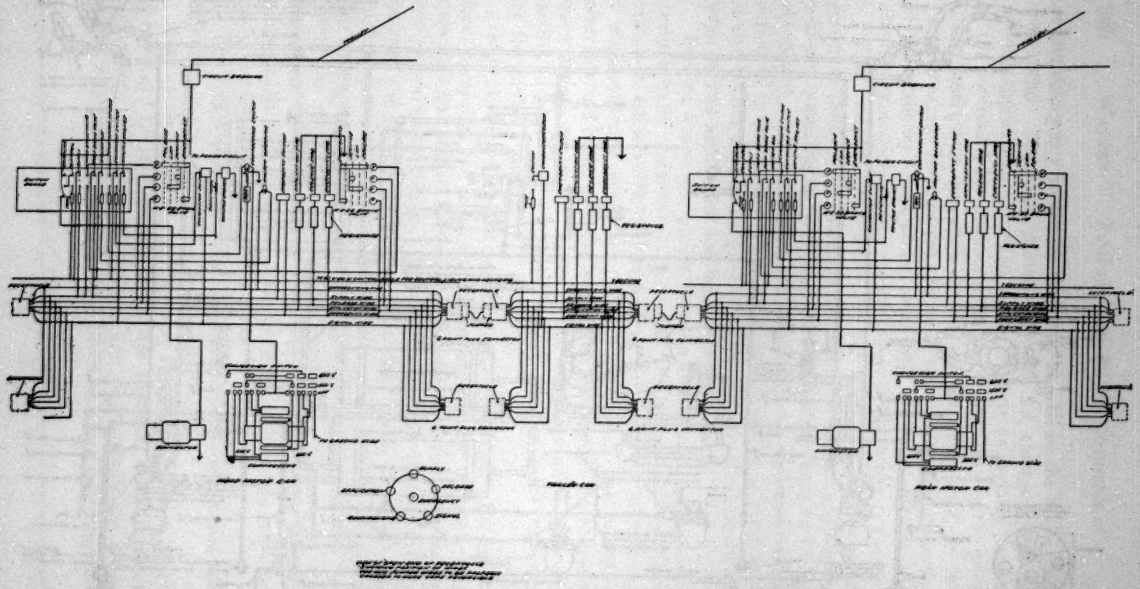
Fig. 17 shows the operating valve for this equipment, which is composed of two distinct parts, one electrical and the other pneumatic. The electrical features are placed above the pneumatic, and consist of:—a rotary drum, having four contacts

FIG. 15.



Piping Diagram.

FIG. 16.



Wiring Diagram.

attached to the same shaft as the rotary valve; and corresponding contact fingers on the body of the valve. The upper finger is connected direct to the trolley, the second to the release magnet line, the third to the application magnet line, and the lower one to the emergency magnet line.

This valve not only has the electric control features embodied, but the pneumatic features are developed to a high degree. The pneumatic improvements in this valve over the ordinary automatic brake valve are: The limiting of the service brake pipe reduction to a predetermined value by means of a reduction limiting valve; the prevention of overcharge of the equalizing reservoir, obtained by the use of a collapsible equalizing discharge piston; the quick response of brake pipe reduction obtained by the combination of direct and equalizing piston exhaust ports.

The valve has six positions, viz., release, holding, handle off, lap, service, and emergency.

Unlike previous designs of electric pneumatic brake valves, the position of the handle is identical for the electric and pneumatic service. With the electric features operative, the service magnet valves reduce the brake pipe pressure on each individual car at the desired rate, but if the electric control is inoperative, the pneumatic control will operate and the brake pipe pressure be reduced at the desired fixed rate by means of the brake valve. The brake pipe reduction is limited to a predetermined amount, the same as in electric service. If any of the service application magnets in the train are inoperative, for any reason, thus causing the brake pipe reduction made by the magnet valves to be less rapid than the reduction of the equalizing reservoir, through the preliminary exhaust port of the brake valve the equalizing piston will lift, open the equalizing discharge valve, and bring the rate of reduction up to the required point. This feature may also be a telltale, and should warn the motorman of any inoperative service application magnets.

REDUCTION LIMITING FEATURE.

The reduction limiting valve, as it is called, is composed of a piston and slide valve, the back of piston and slide-valve chamber being always connected to the equalizing reservoir, and the face always connected to the reduction limiting reservoir.

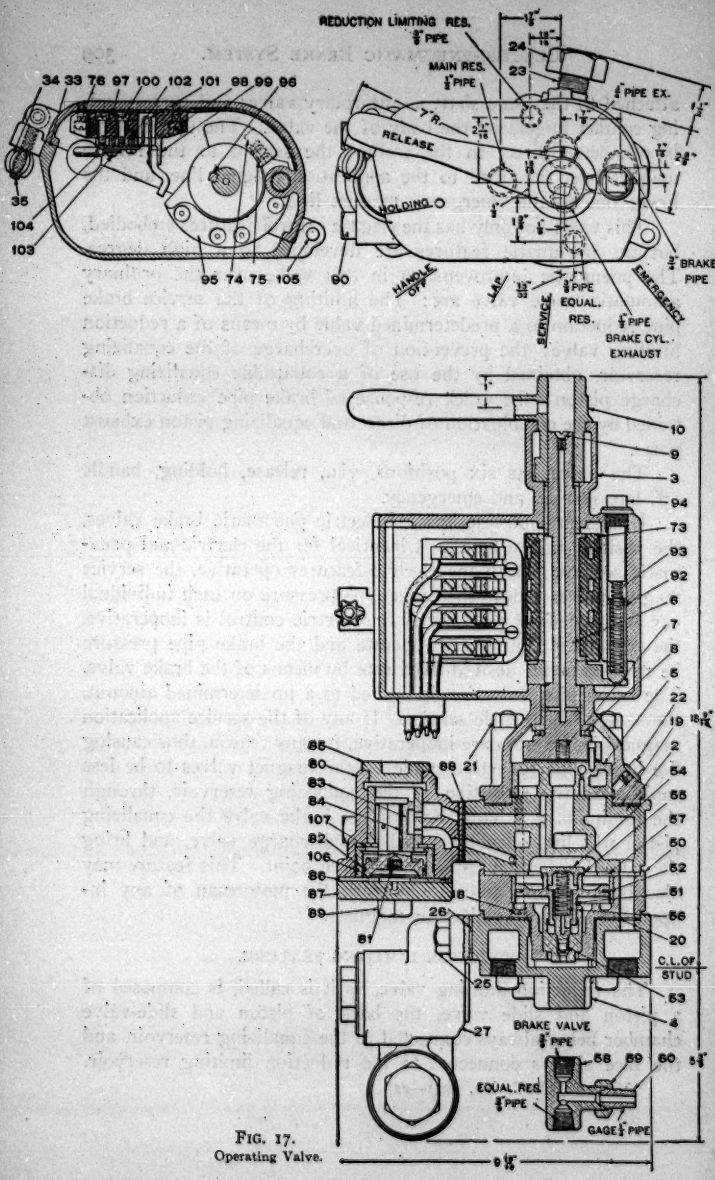


FIG. 17.
Operating Valve.

Normally, the limiting reservoir is connected to the atmosphere, but in service position, while the equalizing reservoir is being reduced through the preliminary exhaust port, the reduction limiting reservoir is being charged. When these pressures are nearly equal, the piston and slide valve will move and cut off communication between the preliminary exhaust and the atmosphere, and, since the equalizing reservoir and direct exhaust ports pass through this slide-valve cavity to the atmosphere, no further reduction can occur through this source; consequently, when the brake pipe pressure has been reduced to the equalizing reservoir pressure, the equalizing discharge valve will seat, thus limiting the brake pipe reduction. No further reduction can now be made unless the brake-valve handle is moved to emergency position. The size of the preliminary exhaust and that of the limiting reservoir charging ports are such that the equalizing and limiting reservoir pressures will be equal at about 50#.

NON-OVERCHARGE OF EQUALIZING RESERVOIR.

The improved design of equalizing discharge valve piston (collapsible type) prevents the overcharge of the equalizing reservoir. Since the equalizing reservoir pressure is on the top of the equalizing piston, and the brake-pipe pressure underneath, if the equalizing reservoir charges faster than the brake pipe a differential will be built up on the upper side of this piston, which will then collapse, allowing pressure in the equalizing reservoir to equalize into the brake pipe through grooves in the piston bush. The spring in this piston will yield with a differential of about 2#.

DIRECT EXHAUST FEATURE.

In service position there is a direct exhaust port leading from the brake pipe to the atmosphere. This insures an immediate reduction of brake-pipe pressure, and eliminates the time element inherent in previous designs of equalizing discharge valve type of brake valves.

In release position of the brake valve, the brake pipe charging port and the equalizing reservoir charging port are open, thus charging the brake pipe and equalizing reservoir to feed-valve

pressure. The reduction limiting reservoir port and the brake cylinder port are open to the atmosphere.

In this position of the brake valve there is no electrical connection made; therefore, the release magnet valve is held open and the emergency and service magnet valves are held closed by their respective springs.

In holding position all port connections are the same as in release, except that the brake-cylinder port is closed. The brake-pipe charging port being open, permits the recharge of the brake pipe and the release of all the brakes in the train but on the head car. Thus the brake on this leading car may be retained, or, if desired, graduated off by moving brake-valve handle between release and holding positions.

As in release, there are no electrical connections made in this position.

In service position the preliminary exhaust port is open, thus reducing the equalizing reservoir pressure *via* the limiting slide-valve exhaust cavity. The reduction limiting reservoir charging port is open, thus charging this reservoir as the equalizing reservoir is being reduced. The equalizing discharge port is open, as is also the direct exhaust port.

In this position of the brake valve the release magnet line remains connected to the supply, and, in addition, the service magnet line is connected, and thus the release and service magnets are energized and release magnet valve is held closed and service magnet valve open.

The handle-off position, as its name implies, is the position of the valve which permits the removal of the handle.

In former designs of pneumatic brake valves the handle is removed in *lap position.*

To permit of the elimination of the brake-pipe cut-out cock, if so desired, the brake-pipe exhaust from the equalizing discharge valve is carried up through the rotary valve and is open in lap position. It will then be evident that this position, *i.e., handle-off,* in which the equalizing discharge is closed, is necessary.

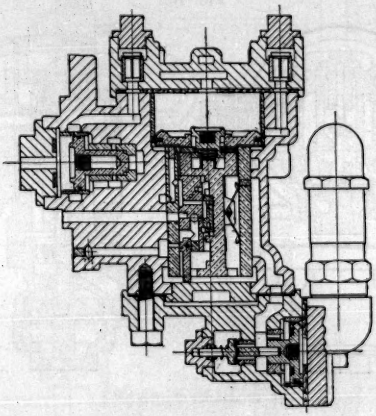
In lap position all ports are closed except the equalizing discharge valve ports; the necessity for this being open is evident, since the brake-pipe exhaust from the equalizing discharge valve

must remain open until the brake-pipe pressure has been drawn down equal to the reduction made in the equalizing reservoir pressure.

In emergency position the brake pipe is connected direct to the atmosphere through a large port, and the emergency magnet line is connected to the supply, thus energizing emergency magnet and opening emergency magnet valve.

The triple valve, which forms a part of this equipment, comprises three main portions, bolted to a suspension bracket (or to a pipe bracket, which, in turn, is bolted to the brake-cylinder pressure head).

FIG. 18.



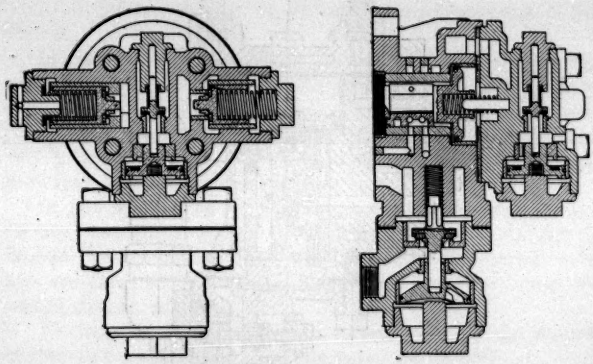
Equalizing Portion.

Fig. 18 shows the *equalizing portion,* in which are: The equalizing piston (with reduction limiting valve); equalizing slide valve and graduating valve, which directly control the pneumatic service application and indirectly the release of the brakes, and the charging of the auxiliary and supplementary reservoirs; the supplementary reservoir check valve, which separates this reservoir from the auxiliary reservoir when a brake-pipe reduction is made; the service port check valve, which prevents back flow of brake-cylinder pressure to the face of the

release piston when releasing the brake; the release piston, which directly controls the release of the brakes; the safety valve, which blows down the auxiliary reservoir pressure in an emergency application; the cut-off piston and valve, which prevent main reservoir air from flowing to the safety valve and to the auxiliary reservoir during an emergency application; the direct and graduated release cylinder cap, which is to be placed in one position or the other, according as a graduated release of the brake is or is not to be provided for.

Fig. 19 shows the *emergency portion*, in which are: The quick-action piston and valve, by means of which brake-pipe air

FIG. 19.



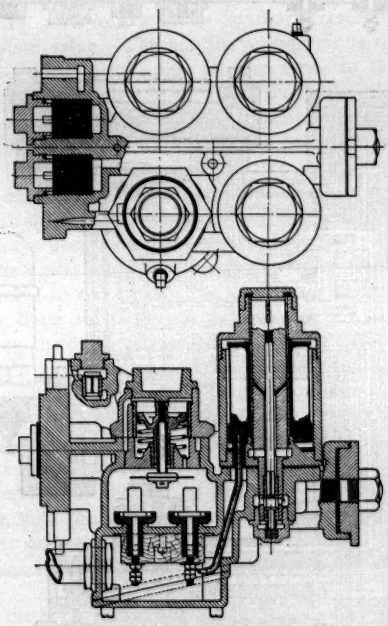
Emergency Portion.

is vented to atmosphere in emergency; the pilot valve, which vents air from the back of emergency valve in emergency application; the emergency valve, which, when open, admits main reservoir air direct to the brake cylinder; the emergency slide-valve piston and slide valve, which control the charging of the quick-action chamber and the quick-action closing chamber, the flow of air from the quick-action chamber to the cut-off valve piston, the flow of air from the quick-action closing chamber to the quick-action piston and emergency switch piston, the flow of air to the face of pilot-valve piston, venting of air from the face of cut-off valve piston and opening of the quick-action chamber maintaining port; the protection valve, which auto-

matically produces quick action when the brake-pipe pressure is reduced to a predetermined value.

Fig. 20 shows the *magnet bracket portion*, in which are: The emergency switch, which is closed at the same time the quick-action valve is opened (by air from the quick-action closing chamber); the service application magnet and valve, by means of

FIG. 20.



Magnet Bracket.

which the service brake-pipe reduction is made at each car; the release magnet and valve, which control the electric release of the brake; the emergency magnet valve, which causes the quick-action parts to operate by venting air from the face of the emergency slide-valve piston to atmosphere; the magnet valve cut-out cap, by means of which either or both of the application magnets may be cut out or cut in.

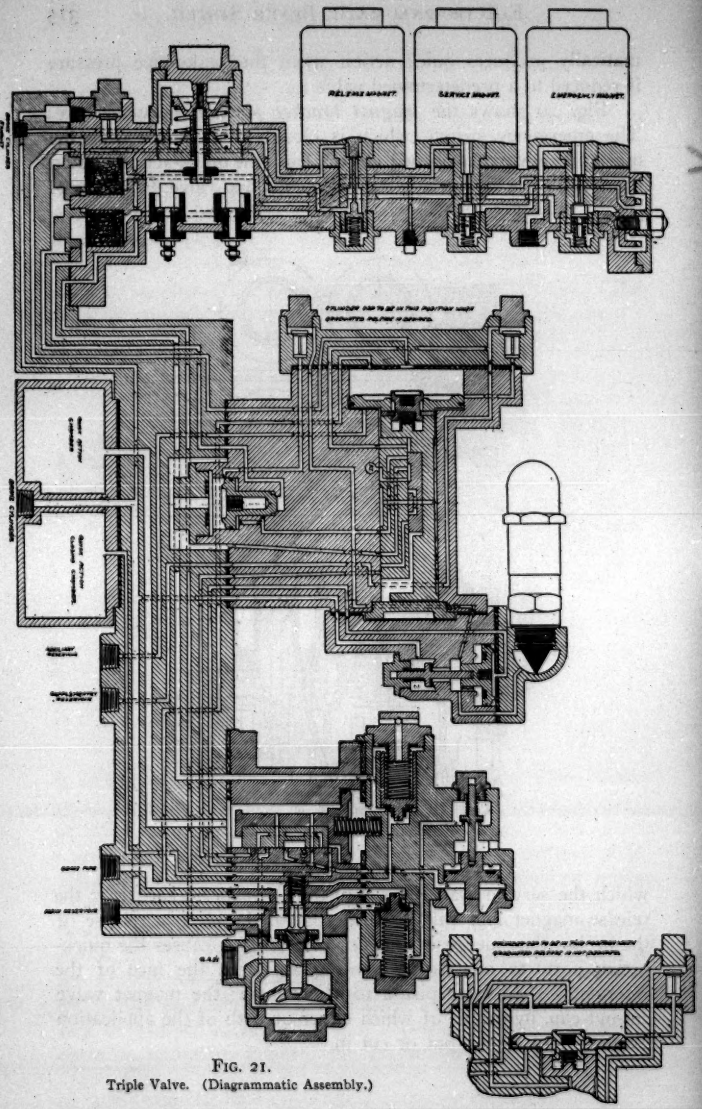


FIG. 21.
Triple Valve. (Diagrammatic Assembly.)

OPERATION OF EQUIPMENT.

Charging Position.

Fig. 21 shows the triple valve diagrammatically. Air from the brake pipe enters as indicated, and flows to the face of the equalizing piston, moving it to release position, thence through the feed groove to the slide-valve chamber and to auxiliary reservoir, and past supplementary reservoir check valve, thence to supplementary reservoir and to auxiliary reservoir, through equalizing slide valve. The auxiliary reservoir is thus charged from two sources. Brake-pipe air also flows to the underside of the quick-action valve. Air from the brake pipe also acts directly on the lower seat of the protection valve, which will remain seated downward until a certain predetermined pressure is reached (governed by protection-valve spring), when it will move very quickly to its closed position, owing to its differential areas, and to the fact that the space at the back of the protection valve is always open to the atmosphere.

With the protection valve closed, the brake-pipe air will flow past this valve to the face of the emergency slide-valve piston, forcing the latter to its release position (if not already there), and charging the quick-action and the quick-action closing chambers through the feed groove around the emergency piston.

The brake pipe is also in communication with the emergency application magnet valve by way of the protection valve and through the strainer and the magnet valve cut-out cap (the latter being in its normal position).

The chamber on the face of the equalizing piston is in communication with the service application magnet valve by way of the strainer and magnet-valve cut-out cap.

ELECTRIC SERVICE APPLICATION.

When the brake-valve handle is moved to application position, the lap position of the valve is passed over, in which position the release magnet circuit is closed, thus energizing this magnet and seating the release magnet valve, which is held closed in service position also. The service application magnet circuit is closed at this time, energizing this magnet, which, in turn, opens the service application magnet valve. This allows air from the brake pipe to flow past the brake-cylinder check valve to the

brake cylinder (or directly to the atmosphere, if desired). The electric service application port is choked down to the proper size to permit of a rate of brake-pipe reduction which will cause the equalizing piston, graduating valve, and equalizing slide valve to move over to service position; but this rate of reduction is not rapid enough to move the emergency piston and slide valve, since, under these conditions, the quick-action chamber pressure can reduce through its feed groove as rapidly as the brake-pipe pressure is being reduced. This insures the desired service application and prevents the possibility of undesired quick action.

The first movement of the equalizing piston and graduating valve toward service position closes the graduated release port, and opens the service port through the slide valve, which, however, has not yet moved, so as to open this port to the brake cylinder.

The first movement of the equalizing piston and graduating valve also connects, through cavity in graduating valve, the port which leads to the face of the large end of release piston, with port leading to the back of this piston, thus balancing these pressures, and, since the small end of this piston is connected to the atmosphere, it will be forced to its closed position, due to the differential areas.

Also, this first movement of the piston and graduating valve opens the resistance-increasing cavity in the face of the equalizing slide valve to atmospheric pressure. This increase in the amount of the under surface of the slide valve, which is exposed to the atmosphere, increases the resistance which has to be overcome before the equalizing slide valve can be moved. The object of this is two-fold: First, to reduce the sensitiveness of the valve sufficiently to prevent fluctuations in brake-pipe pressure, due to the feed valve or other causes, from producing undesired light-service applications or brakes creeping on; second, to insure the making of such a brake-pipe reduction in applying the brakes that no trouble in releasing can result from inability to establish sufficient differential, as may be the case where the brakes will apply on a very light brake-pipe reduction.

It will be noted that the first movement of the equalizing piston in returning toward release position disconnects the resistance-increasing cavity from the atmosphere and re-establishes

its communication to the auxiliary reservoir, so that the added resistance to motion is at once eliminated, and the valve will consequently be easier to release than to apply.

When sufficient differential has been established to cause the equalizing piston to move the slide valve to its service position, the opening of the service port permits air to flow from the auxiliary reservoir past the graduating valve, and through the slide valve to the brake cylinder by way of the release piston, service port check valve, and cut-off valve. The brake-cylinder pressure will continue to be increased in this manner until it equalizes with the auxiliary reservoir, or (in case a full service reduction in brake-pipe pressure is not made) until the auxiliary reservoir pressure is reduced to a point slightly lower than the pressure in the brake pipe. In the latter case, the equalizing piston and graduating valve will move back until the piston stops against the slide valve in service lap position, which closes the service port and prevents a further building up of brake-cylinder pressure, and opens the resistance-increasing port to auxiliary reservoir pressure, thus again balancing the slide valve and rendering it more sensitive to release than it was to apply.

The service application magnet may be held energized, thus holding the service application magnet valve open and causing a continuous brake-pipe reduction, which permits the auxiliary and brake-cylinder pressure to equalize (giving a full service application of the brakes), or it may be energized for shorter periods of time, thus causing partial brake applications to any desired degree, after which the parts will move to service lap position, as above mentioned. This energizing of service application magnet may be repeated as many times as desired, each time causing an increase in brake-cylinder pressure, corresponding to the amount of brake-pipe reduction, until equalization takes place.

REDUCTION LIMITING FEATURE IN THE EQUALIZING PISTON.

Ordinarily, the service magnet makes a brake-pipe reduction by connecting the brake pipe to the brake cylinder; this then means that these two pressures are approaching each other, and as they near the equalizing pressure the rate of reduction in the brake pipe is gradually decreasing to zero.

In order to procure the desired pressure in the given time, then, the rate of reduction at first is quite rapid and the margin

between it and the emergency rate is very small, and this margin is broadened as equalization is approached.

For those who may desire to have a uniform margin between the service and emergency rates of reduction, provision has been made to close the service magnet connection to the service brake cylinder and open same to the atmosphere. Then, in order to limit the brake-pipe reduction to the equalization point, the reduction limiting check valve is embodied in the equalizing piston.

When the service magnet valve is open, and the equalizing piston is moved over toward service position, the reduction in auxiliary reservoir pressure which follows the opening of the service port stops the movement of the equalizing parts before the reduction limiting check valve seats against the cylinder cap gasket.

If a continuous brake-pipe reduction is made, the equalizing parts will remain in this position until the auxiliary reservoir and brake-cylinder pressures have equalized; then a further reduction in brake-pipe pressure will cause these parts to be moved by the higher auxiliary reservoir pressure, until the reduction limiting valve seals against the cylinder cap gasket, thus preventing an over-reduction in brake-pipe pressure.

ELECTRIC EMERGENCY APPLICATION.

With the brake-valve handle in emergency position, the emergency application magnet circuit is closed, energizing this magnet, which, in turn, opens the emergency application magnet valve and allows air from the brake pipe to flow to the atmosphere. This opening through the emergency application magnet valve to the atmosphere is of such size as to permit of a rate of brake-pipe reduction which will cause the emergency slide-valve piston and its slide valve to move to emergency position, and also the equalizing piston, graduating and equalizing slide valves to move over until the piston rests against the cylinder cap gasket.

With the equalizing piston, graduating valve, and slide valve in emergency position, the auxiliary reservoir is connected to the safety valve the same as in service operation. Consequently, the pressure in this reservoir will be reduced by the safety valve to the point at which it closes. This reduction of auxiliary reservoir pressure in emergency insures that the brake will be easily released thereafter.

With emergency slide valve in emergency position, air flows through the slide valve from quick-action closing chamber to the quick-action piston, thus forcing the quick-action valve open, thereby venting brake-pipe air to the atmosphere (which causes a sudden local brake-pipe reduction that starts pneumatic quick action); and to the emergency switch piston, thereby closing the emergency switch, which serves as a circuit-closer to cause simultaneous quick action throughout the train when originating pneumatically.

The quick-action valve will remain open and emergency switch closed until the quick-action closing chamber drains by way of the quick-action exhaust to the atmosphere through small drilled port in quick-action piston.

Also, in this position of the emergency slide valve, the port leading to the face of the cut-off piston is connected to the atmosphere through the cavity in the slide valve; thus cut-off valve will be closed by its spring.

Air also flows from the quick-action chamber through the emergency slide valve to the face of the pilot-valve piston, thus opening the pilot valve and venting air from the back of the emergency valve to the atmosphere. Since main reservoir pressure is exerted on the face of the emergency valve, this valve will be then forced open very quickly, allowing main reservoir air to flow direct to the brake cylinder; the cut-off valve, being closed, prevents main reservoir air flowing to the safety valve or to the auxiliary reservoir, thus giving full main reservoir pressure in the brake cylinder.

A connection is also made in this position from the quick-action chamber to the auxiliary reservoir. Then the air in the auxiliary reservoir is made to maintain the quick-action chamber pressure (since its volume is quite small) against possible leakage past the pilot-valve piston, thus insuring that the pilot valve will remain open, thereby maintaining the high-brake cylinder pressure in emergency.

ELECTRIC RELEASE AFTER SERVICE APPLICATION.

When it is desired to release the brake, the brake-valve handle is moved to release position, in which the release magnet circuit is open, and this magnet is de-energized, allowing the release

magnet valve to be opened by its spring. The brake-pipe charging port in the brake valve is also open, restoring the air in the brake pipe to its initial pressure. This increase in the brake-pipe pressure forces the equalizing piston, graduating and equalizing slide valves to release position in which the brake-cylinder air is exhausted to the atmosphere, by way of the cut-off valve, release piston, and release magnet valve. If the brake valve is allowed to remain in this position, the brake-cylinder air will be exhausted in the shortest possible time.

ELECTRIC RELEASE AFTER EMERGENCY APPLICATION.

After an emergency application has been made, the quick-action valve will remain open and the emergency switch closed until the quick-action closing chamber air has drained to the atmosphere through the small drilled port in quick-action piston, after which the quick-action valve will be closed and the emergency switch opened by their respective springs.

With the quick-action valve closed and the brake-pipe pressure being restored, the protection valve will be the first to go to its normal (release) position, which will, in turn, admit air to the face of emergency slide-valve piston, forcing it to release position and charging quick-action and quick-action closing chambers, as described under "Charging." Brake-pipe pressure has also been built up on the face of equalizing piston, forcing it, with its valves, to release position. With emergency slide valve in release position, the chamber on the face of the pilot-valve piston is connected to the atmosphere. The pilot valve will then be closed by its spring. The emergency valve will remain open until the pressures on the front and back of this valve have equalized through the small drilled port, when it will be closed by its spring. Quick-action chamber air also flows to the face of the cut-off valve piston, thereby opening the cut-off valve and allowing the exhaust of the high-pressure cylinder air past the cut-off valve, small end of the release piston, and the release magnet valve.

GRADUATED RELEASE.

The release of the brake may be graduated by moving the brake-valve handle between release and lap positions. The brake-pipe charging port of the brake valve is open in release position;

therefore, the equalizing parts of the triple valve will be moved to release position. In this position the cavity in the graduating valve connects to the atmosphere the port leading to the face of the large end of the release piston, which will then be forced open, due to the brake-cylinder pressure on the back. In release position of the brake valve the release magnet circuit is open; this magnet is then de-energized and release magnet valve is then held open by its spring. Brake-cylinder air can then flow to atmosphere past the cut-off valve, small end of release piston and release magnet valve; but when the equalizing slide valve is in release position and the graduated release cylinder cap in the position marked "graduated release," the graduated release port is open, which connects the supplementary and auxiliary reservoirs. This former volume was not used in service operation and will still have its initial pressure. The supplementary reservoir air flowing back into the auxiliary reservoir will quickly raise the pressure in the latter to a point which is slightly in excess of that in the brake pipe, and, consequently, the equalizing piston and graduating valve will be moved to graduated release lap position, in which the graduated release port is closed. But the cavity in the graduating valve connects the ports leading to the back and to the face of the large end of release piston, thus balancing these pressures. This piston will then be forced to closed position, due to the differential areas, cutting off the release of brake-cylinder pressure. No further reduction of brake-cylinder pressure can now be made until the brake-pipe pressure is again increased and equalizing piston and graduating valve moved back to release position.

Even with the direct and graduated release cap in "direct release" position, which closes the supplementary reservoir connection to the auxiliary reservoir, it is always possible (when the electric features are operative) to graduate the release of the brake by means of the release magnet valve alone, if the brake-valve handle is moved between release and lap positions.

PNEUMATIC OPERATION.

In case any of the electric features should be inoperative, through loss of current or other causes, the equipment may be operated as any of the older types, the brake-pipe reductions then

being made by means of the brake valve alone (the positions of the brake-valve handle being the same for both electric and pneumatic operation).

PNEUMATIC SERVICE APPLICATION.

With the brake-valve handle in service position, the preliminary exhaust port in the brake valve is opened, allowing equalizing piston to lift and produce a rate of brake-pipe reduction sufficiently rapid to move the equalizing piston, graduating and slide valves to service position. The rate of reduction as fixed by the brake valve is, however, not as rapid as that at which the quick-action chamber pressures can be reduced through its feed groove into the brake pipe, thus positively guarding against undesired quick action.

The flow of auxiliary air into the brake cylinder is the same in pneumatic as in electrical service operation.

PNEUMATIC EMERGENCY APPLICATION.

With brake-valve handle in this position, the emergency exhaust port is open and permits of such a rapid rate of brake-pipe reduction that the quick-action chamber pressure cannot reduce as rapidly through its feed groove as the brake-pipe pressure is being reduced through the brake valve. Consequently, the emergency piston and its slide valve are moved to their emergency positions. The equalizing piston has also moved (carrying with it the slide valve and graduating valve) against the cylinder cap gasket.

The operation of the various valves is now the same as previously described under " Electric Emergency Application."

PNEUMATIC GRADUATED RELEASE.

This is accomplished in the same manner as previously described, except that the release magnet valve is open at all times, and the graduated release controlled entirely by the release piston.

PROTECTION FEATURE.

In case there is excessive leakage, after a full service application has been made, which will reduce the brake-pipe pressure to a certain predetermined point, the protection valve will

be forced open by its spring, thus connecting the face of the emergency slide-valve piston to the atmosphere, past the protection valve seat, and producing a rate of brake-pipe reduction that will cause emergency piston and slide valve to move to emergency position, thus causing quick action as previously described.

(To be continued)

Synthetic Rubber, by the Production and Polymerization of Butadiene, Isoprene, and Their Homologues. W. H. PERKIN, JR., F.R.S. (*Jour. Soc. Chem. Ind.*, xxxi, No. 13, 616.)—This article is exceedingly interesting and contains the history of the production of synthetic rubber. A concise summary follows. There can be no doubt that rubber may be obtained synthetically by the polymerization of isoprene and its homologues, and that the synthetic product is really rubber and strictly comparable to natural rubbers. These facts have been confirmed by a large number of chemists working independently. There is no doubt that Tilden prepared specimens of crude synthetic rubber in 1882 and 1884, long previous to those produced in 1909 by Bayer & Co., of Elberfeld, which have been claimed as the first true samples of synthetic rubber. Greville Williams was the first to isolate isoprene from the products of the destructive distillation of rubber in a fairly pure state, and was the first to observe the transformation of this hydrocarbon into a rubber-like body. This was in 1860. It is clear that he considered that both caoutchouc and gutta-percha are polymers of isoprene. The article then gives a detailed account of several methods of obtaining rubber synthetically, which are: firstly, the preparation of isoprene from *iso*amylalcohol and its subsequent polymerization (this process depends for its success on the discovery of some cheap method of obtaining *iso*amylalcohol in quantity); secondly, the conversion of butyl alcohol, obtained cheaply and in any quantity by Professor Fernback's new method of fermentation, into butadiene; and, thirdly, the conversion of aldehyde through aldol into butadiene, the butadiene being then, in each case, polymerized to butadiene rubber by Dr. Mathews's sodium polymerization process.

National Association of Cotton Manufacturers.—The 93rd Semi-Annual Meeting will be held at The Griswold, near New London, Conn., on September 9th, 10th, and 11th. The following are among the subjects which will be discussed at the meeting: Cotton Growing in India; Economic Use of Lubricating Oils; Lithographic Method of Printing Cotton; Raising Cotton in California; Spinning Value of Different Grades of Cotton; Tape Driving for Spindles; Wastes in Cotton Manufacture. A full programme will be issued shortly before the meeting.

Groups of Electrons in a Sphere of Positive Electricity. A. E. HAAS. (*Akad. Wiss. Wien. Ber.*, CXX, 2a, 1111.)—In Thomson's electronic model of an atom it is a necessary condition of equilibrium that the central attraction on any electron shall be equal to the resultant repulsions of the other electrons and shall also be in the same direction. This condition is not fulfilled in an outer ring of 11, and an inner ring of 7 electrons, and one electron at the centre of the sphere of positive electricity. This work is a mathematical search for stable groups fulfilling the condition of equilibrium stated above. The types considered comprise similar and concentric regular polygons, double pyramids, prisms, and concentric regular polyhedra. An interesting result is reached concerning the maximum number of electrons capable of forming a ring in equilibrium, but not necessarily stable. It proves to be 471, as against Thomson's maximum of 5 for stable equilibrium; 471 is just double the atomic weight of uranium. Another result is that when there is equilibrium in a state of rest, and rotation supervenes, the new configuration of equilibrium is geometrically similar, but all the linear dimensions are increased in the same ratio.

Formation and Velocity of Negative Ions in Canal Rays. J. KOENIGSBERGER and J. KUTSCHEWSKI. (*Deutsch. Phys. Gesell. Verh.*, XIV, 1, 1.)—Many observers are of opinion that the negative ions in oxygen are due to the presence of water vapor in the discharge tube, and possibly of other compounds containing oxygen. The same explanation serves for the negative ions in hydrogen. It is now found that all canal-ray ions are originally positive, irrespective of whether they become positive or negative later. The velocity of the negative portion is always smaller than that of the positive. The formation of the negative ions is caused at the seat of ionization more particularly by rays of smaller velocity.

Use of Manganese in Nickel Alloys. ANON. (*Brass World*, VIII, 6, 191.)—Manganese is known as a good deoxidizer of these alloys. It is usually added alone, which is not a good method because it melts at about the same temperature as steel, which is much higher than the melting point of nickel alloys. It is true that it will melt in these alloys if given sufficient time, but as a rule the time allowed is much too short and the bulk of the manganese is removed with the skimmings. The proper way to add it is to make a rich copper manganese alloy, containing 70 per cent. copper and 30 per cent. manganese, by melting the two together, stirring them and pouring out into small bars. This alloy, called manganese copper or cupro-manganese, is added to the metal or alloy in the proportion of about 5 ounces to 100 pounds of the molten metal. It is introduced after the metal has melted, and not allowed to melt with the other metals.

NOTES FROM THE BUREAU OF STANDARDS.

SELECTIVE RADIATION FROM VARIOUS SUBSTANCES.

BY
W. W. Coblentz.

THE present paper contains further contributions to the study of the radiating properties of various substances (see Nos. 91, 97, 131, 156). This includes a determination of (I) the radiation constants of platinum (see No. 105), (II) the emission spectrum of neon, helium, and mercury, (III) the emissivity of different parts of the acetylene flame, (IV) the variation of emissivity with thickness of the radiating layer, oxides, (V) the radiation from a uniformly heated cavity and from its enclosing walls, (VI) standard spectral energy curves, and, (Note I) light filters which absorb all the infra-red (see No. 168).

The spectral energy curves of these sources of radiation were examined by means of a vacuum bolometer, mirror spectrometer, and fluorite prism.

The radiation constants of platinum were obtained from spectral energy curves, the temperatures being measured by means of an optical pyrometer and also by means of a fine wire thermocouple. The two methods of temperature measurement give concordant results, which confirm the previous conclusions that the radiation constants are complex functions of the temperature.

The high radiant efficiency of vacuum tubes is owing to the small amount of infra-red radiation that is emitted. Neon is unique in having the maximum emission in the visible (red) part of the spectrum. This explains the low energy input (high efficiency) required to excite this gas to light emission. In the helium and in the quartz mercury lamps there are intense infra-red emission lines which lower the radiant efficiency. In the mercury vapor lamp it was found that the infra-red and the yellow lines increase in the same proportion with increase in energy input; but the intense green line does not increase at the same rate in intensity, although it is the most easily excited to light emission. Hence, after exceeding a given energy input,

there is a decrease in the radiant efficiency. For the intensity of the yellow line, increasing as it does in the same proportion as the infra-red, is not sufficient to counterbalance the loss by radiation in the infra-red, and the result is a decrease in the ratio of the luminous to the total radiation emitted.

THE STANDARDIZATION OF POTASSIUM PERMANGANATE SOLUTION BY SODIUM OXALATE.[1]

BY

R. S. McBride,

Assistant Chemist.

IT was desired to determine the effect of the variation of the following factors upon the result obtained in the standardization of potassium permanganate by sodium oxalate, viz.: temperature, acidity, volume of solution, rate of addition of the permanganate, access of air, presence of added manganous sulphate, and, in connection with these, the corrections necessary upon the apparent end-points. In order to accomplish such determination the factors were varied one at a time, noting the effect, if any, produced upon the apparent value of the permanganate. Each of the factors was found to have a definite, though small, influence upon the result.

The effects were undoubtedly due to a variation of the reaction from the normal course as usually given. Such variations might tend to cause the use of an excess of either permanganate or oxalate; or both sorts of influence might operate at the same time, in equal or unequal degree. The nine possible sources of variation are: (*a*) loss of oxalic acid by volatilization, (*b*) decomposition of oxalic acid by water, (*c*) decomposition of oxalic acid by sulphuric acid, (*d*) oxidation of oxalic acid by the air, (*e*) incomplete oxidation of the oxalic acid, (*f*) liberation of oxygen during the reaction, (*g*) incomplete reduction of the permanganate to the manganous state, (*h*) presence of impurities in the oxalate of either greater or less reducing power, and (*i*) formation of other products of the oxidation than carbon

[1] Abstract, Bulletin of the Bureau of Standards, vol. 8.

dioxide and water. Of these, only two appeared to be at all probable, viz., loss of oxygen and atmospheric oxidation of the oxalic acid; and, furthermore, only the first of these two could be held in the light of all of the experiments reported.

If the main source of error is due to an oxygen loss, the higher values obtained in the various series must be taken as correct. On this basis the following method of titration is recommended: in a 400 c.c. beaker dissolve 0.25–0.3 g. of sodium oxalate in 200 to 250 c.c. of hot water (80–90°) and add 10 c.c. of 1 : 1 sulphuric acid. Titrate at once with N/10 $KMnO_4$ solution, *stirring the liquid vigorously and continuously.* The permanganate must not be added more rapidly than 10–15 c.c. per minute, and the last ½ to 1 c.c. must be added dropwise, with particular care to allow each drop to be wholly decolorized before the next is added. The solution should not be below 60° by the time the end-point is reached. The excess of permanganate used to cause the end-point color must be estimated by matching the color in another beaker containing the same bulk of acid and hot water.

Under the above condition the agreement of duplicates should be at least 1 part in 2000; and the variation from absolute accuracy of average values is probably not greater than 0.05 per cent. Under other conditions than those described it is possible to obtain correct results; but, using the procedure recommended, the difficulties of the titration are reduced to a minimum.

"ELECTRIC WIRE AND CABLE TERMINOLOGY."[1]

ON account of the growing need for precise definitions in the field of conductor terminology, the Standards Committee of the American Institute of Electrical Engineers requested the Bureau of Standards to prepare a circular on the subject. As a result of extensive correspondence and consultation it was found possible to formulate a reasonably consistent body of definitions without introducing radical departures from existing general practice. Seventeen of the most important terms have been defined.

It was found necessary to give the most care and thought to

[1] Abstract, Circular of the Bureau of Standards, No. 37, 1912.

the terms "strand" and "cable." In the strong preponderance of current opinion, "strand" implies a component part of a cable or stranded conductor, each part being either a combination of wires or a single wire. It fortunately happens that this is precisely in accord with the non-technical meaning of "strand." A "cable" is defined as either (1) a stranded conductor, *i.e.*, a conductor composed of a group of wires, or (2) a combination of conductors insulated from one another. The first kind of cable may be either bare or insulated. The component conductors of the second kind of cable may be either solid or stranded, and the whole may or may not have a common insulating covering.

From the main terms defined, the minor terms should follow logically, and most or all of the confusion which has existed on this subject should disappear.

Pottery Found by Excavation at Susa. A. GRANGER. (*Comptes Rend.*, cliv, 1162.)—The Morgan mission deposited ware and fragments at the Louvre which belong to what are termed "the first and second periods," the earlier being superior in execution and finish. Some pieces were hand worked and the rest turned. Ware of the same epoch showed evidences of great difference in the skill of the makers. The local clay is a ferruginous marl of the composition:—clay 28.57, sand 27.10, chalk 37.58, combined water 4.05, and moisture 2.70 per cent. It melts to a brown glass at 1400° C. The pottery was fired at less than 1000° C. Kilns were found, but in such ruinous condition that it was impossible to reconstruct them. The stains used in the ware were iron and a little manganese, probably found as a natural manganiferous iron oxide. In the "first period" the stain was fired with a flux, in the "second period" it was simply brushed on and not fired.

The Disappearance of Higher Boiling Phenols in Creosoted Wood. S. CABOT. (*J. Ind. Eng. Chem.*, iv, 266.)—The higher-boiling coal-tar phenols on prolonged exposure to air become converted into tarry substances insoluble in benzene but soluble in acetone. A portion of this tarry matter is insoluble in 10 per cent. sodium hydroxide solution, but soluble as an alkali salt in water, a portion forms a salt with alkali that undergoes hydrolysis on solution; and a third portion has a very slight affinity for alkali. The higher-boiling phenols remain in creosoted wood in the form of complex oxidation products.

FRANKLIN INSTITUTE

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The Half-Tone Process, a practical manual of photo-engraving in half-tone on zinc, copper, and brass, with chapters on three-color work and photo-lithography for offset printing by Julius Verfasser. Fifth edition, fully revised. 378 pages, illustrations, plates, colored frontispiece, 8vo. London, Iliffe & Sons, Ltd., no date. Price, 7 shillings 6 pence.

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BOOK NOTICES.

METHODS OF ORGANIC ANALYSIS, by Henry C. Sherman. Published by the Macmillan Company, New York. (2nd edition.) 407 pages, 21 x 14 cm. Price, $2.40.

This book is an advanced laboratory manual of organic analysis, both proximate and ultimate. The order of topics corresponds roughly to that usual in text-books of organic chemistry. However, the scope of the book

is broad, and it is not restricted to topics of purely scientific interest. Practical matters such as oils and fats, sugars, soap and food-preservatives receive very detailed discussion, while the treatment of the subject of fuels is the best that the reviewer has seen. The only criticism which occurs to the reviewer is that the whole character of the book seems somewhat advanced for the class of students for whom it is intended—third-year men in the chemical course at Columbia University. The reviewer has met few third-year students who could successfully use a work of this sort without much additional guidance from the instructor.

The book is clearly and concisely written. There are few illustrations, but the bibliographies are unusually complete, and there are many references to the journal literature. There is a good index.

ROBERT H. BRADBURY.

INDUSTRIAL ORGANIC CHEMISTRY, by S. P. Sadtler. Published by J. B. Lippincott Company, Philadelphia. (4th edition.) 601 pages, 23.5 x 15 cm. Price, $5.00.

The reviewer has found it an interesting task to examine this book, since he had the pleasure, twenty years ago, of hearing the lectures of which the book is the outgrowth. These lectures were delivered when Dr. Sadtler was Professor of Organic and Technical Chemistry in the University of Pennsylvania.

The book fills a middle space between the large exhaustive special works and the smaller students' hand-books, like Post, Medicus and Ost in German, Payen in French, and Frank Hall Thorp in English. The difficulties which stand in the path of the author of a work of this kind are very great. It is an unfortunate fact that technical journals do not attain to quite the same high standard of reliability as purely scientific publications. Further, the problem of adopting a consistent, symmetrical, well-balanced treatment, and adhering to it throughout, is not an easy one.

The present work gives constant evidence that the author has appreciated the difficulties of his task and has been willing to take the trouble to overcome them. The revision has been thorough and the book appears to be completely abreast of the present state of the subject. The sections on special analytical methods will be of interest to the working chemist. There are few references to the journal literature, but the bibliographies at the ends of the sections are complete and up to date. The book fills a vacant place in the literature, and fills it well. It should be of great service, not only to chemists but also to teachers.

ROBERT H. BRADBURY.

ANALYST'S LABORATORY COMPANION, by Alfred E. Johnson. Published by P. Blakiston's Son & Co., Philadelphia. (4th edition.) 164 pages, 18.5 x 12 cm. Price, $2.00.

While this book contains some descriptive matter, it is, in the main, a collection of numerical data intended for the commercial analyst. There are tables of atomic weights, percentage compositions, conversion factors

for gravimetric analysis, factors for volumetric work, special tables for water analysis, tables for sugar analysis, tables of Reichert-Meissl values, and countless other tables. Most of the data have been recalculated so as to be in accord with the international atomic weights for 1912. The five-place logarithm of each factor is given. The book is a serviceable compilation, which should be very helpful to the practical analyst.

ROBERT H. BRADBURY.

CHEMICAL ARITHMETIC AND CALCULATION OF FURNACE CHARGES, by Regis Chauvenet. Published by J. B. Lippincott Company, Philadelphia. 302 pages, 22.5 x 15 cm. Price, $4.00.

This is a book of rather unusual type. The first two-thirds is devoted to an elaborate and detailed treatment of the whole subject of chemical calculations, covering somewhat the same ground as Biehringer's "Stochiometrie." Illustrative problems are worked out and a large number of problems for class-room work is provided. There are some amusing and pertinent remarks on the unwisdom of stating results to half a dozen decimal places when the limit of accuracy of the method used is reached in the first. The author is to be congratulated on having given the answers to all of his problems. It is a curious anomaly that books in chemical arithmetic are frequently published without answers. The fact is that any teacher can invent without difficulty all the problems he needs for his classes. The difficulty arises in trying to get time in the class-room to do the arithmetical work of solving them, and when, as is often the case, each student is working at a different problem, the difficulty becomes an impossibility. A problem book without answers is little better than waste paper.

The last third of the book is devoted to the application of the principles of chemical arithmetic to the problems that arise in the calculation of furnace charges in iron and copper metallurgy. The book seems to be intended mainly for students and teachers of metallurgy, and it should have a useful career.

ROBERT H. BRADBURY.

PENROSE'S PICTORIAL ANNUAL. The process year book. Edited by William Gamble, 1911–1912, vol. 17, 224 pages of text, 80 pages of illustrations, and numerous plates. 8vo. London, A. W. Penrose & Co., Ltd. American agents, Tennant & Ward, New York, N. Y. Price, in cloth, $2.50.

The volume, which recently appeared from the press, contains the usual number of interesting and valuable contributions to the process engraver's art from workers in all parts of the world. The specimens of half-tone illustrations and color plates give an indication of the progress made during the past year, and the color work includes examples made by various processes and in several colors—from one to five. The presswork and binding have received the same care and attention as those of previous issues.

CARNEGIE INSTITUTION OF WASHINGTON. Publications: The following volumes are now in press:

Barus, Carl—The Production of Elliptic Interferences in Relation to Interferometry. Part II. 8vo.

Stager, Henry W.—A Sylow Factor Table of the First Twelve Thousand Numbers, Giving the Possible Number of Sub-groups under Sylow's Theorem of a Group of Given Order between the Limits of 0 to 12,000.

Lehmer, Derrick N.—Tables Giving a Complete List of Prime Numbers between the Limits 1 and 10,006,721. Folio.

Benedict, Francis G.—The Composition of Atmospheric Air. 8vo.

Benedict, Francis G., and Walter G. Cady.—A Bicycle Ergometer with an Electric Brake. 8vo.

Jones, Harry C.—The Electrical Conductivity, Dissociation, and Temperature Coefficients of Conductivity (from Zero to Sixty-five Degrees) of Aqueous Solution of a Number of Salts and Organic Acids.

CURRENT TOPICS

Ammonia and Nitric Acid from the Atmosphere. PROF. A. W. CROSSLEY D.Sc., F.R.S., (*Engineering*, xciii, 2418, 599.)—This is an abstract of two lectures delivered at the Royal Institution, London. This article deserves careful consideration; the chief points are as follows. The cycle of the changes of nitrogenous matter in the household of nature is: Plants take up nitrates and ammonium salts from the soil and build up organic compounds, which form the food of animals. In the animal system the nitrogenous matter is transformed into proteins to form tissues, and some nitrogen is secreted again as urea and returned to the soil; there the compounds are broken down and re-transformed into nitrates and ammonia again by bacterial action. Unfortunately the wastage in this cycle is enormous at several stages, especially as regards the sewage, some nitrogen is also liberated as such and returned to the atmosphere. Electric discharges in the atmosphere and certain bacteria could fix part of the atmospheric nitrogen; but these sources of supply are quite insufficient and other sources must be sought. The present sources, *e.g.*, guano-beds and Chili saltpetre, might last another twenty to forty years. Ammonium sulphate was produced in great quantity, but still the supply was insufficient. The atmosphere contained some 4,000 billion tons of nitrogen and that above each acre about 32,000 tons of nitrogen, which had to be utilized. The synthetic production of ammonia did not look very hopeful so far. It was known that magnesium would fix atmospheric nitrogen as magnesium nitride, which when decomposed by steam, yielded ammonia; aluminum probably would do the same. Nitrogen is also fixed by the alkaline earth carbides, forming nitrolim, which is a mixture of carbon and calcium cyanamide. This nitrolim was utilized as a manure, or was transformed into other chemical products. Much atmospheric nitrogen was directly oxidized by the electric discharge.

New Composite Sheet Metals. ANON. (*Brass World*, viii, 5, 176.)—The high price of tin has made it desirable to replace it with a cheaper metal. The Hoyt Metal Co., of St. Louis, Mo., have succeeded in producing some very interesting compound soft metals with an aluminum core. The *Hoyt-Silver* is a Britannia metal with a core of aluminum. It will make silver plated ware that is cheaper, stiffer, lighter and stronger than that made from Britannia metal. Its use saves 4 to 5 cents a pound. Sheet as thin as No. 26 B and S gauge is supplied up to 24 inches wide. Hoyt-silver

is not suitable for toilet-ware, but another new material called "two-ply Britannia" is supplied for this purpose. *Alumintin* is sheet aluminum faced on both sides with pure block tin. It can be soldered and electro-plated without difficulty. Its specific gravity is 3.34. Such a light material that can be worked like copper will be much appreciated. It is supplied in sheets of the same dimensions as "Hoyt-Silver." *White Copper Stamping Metal* is sheet aluminum faced on both sides with an antimonial lead alloy. It is cheaper and more easily worked than copper or brass, and is stiffer and harder than antimonial lead. It is used for the manufacture of badges, fobs and medals. Its specific gravity is 5.10. It can be stamped into intricate designs without annealing. The dies are not worn, and it can be readily electro-plated. The Hoyt Metal Co. state that these metals are made by a rolling process, which they do not wish to divulge at the present time.

A New Pyrophoric Alloy. ANON. (*Brass World*, viii, 5, 180.)—The usual pyrophoric alloy, used for self-igniting match boxes or gas lighters, consists of 70 per cent. cerium and 30 per cent. iron. A German inventor has found that alloys of manganese and antimony are also pyrophoric and are cheaper than the cerium alloys. For certain purposes it is an improvement to add 10 per cent. of chromium, and during the melting of the alloy it is an advantage to add a very small quantity of aluminum or magnesium to increase fluidity and soundness. The proportions found best are:—

Manganese	80 per cent.
Antimony	10 per cent.
Chromium	10 per cent.

Instead of giving a shower of sparks like the cerium alloys, it produces a long streak of flame, thus making the friction wheel unnecessary. The alloy is air proof and does not disintegrate like the cerium alloy.

Drying Blasts with Calcium Chloride. HEYM. (*Oester. Z. Berg.-Hüttenw.*, lix, 603.)—The cost of plant construction for drying air by calcium chloride is only one-quarter that of a Gayley refrigerator plant of the same capacity. The cost of maintenance is less, also. The method followed is: crushed calcium chloride is sifted to get the fine portion at the bottom and the coarse on top. A spiral tube is inserted in this layer for the circulation of water. The air to be dried is blown through the layer of calcium chloride from above. The heat evolved by the absorption of the moisture is carried off by the water circulating in the tube, which prevents an increase in temperature, as the power of calcium chloride to absorb moisture diminishes the higher the temperature. Care must

be taken that the calcium chloride does not get wet. To regenerate it, it must be gradually heated to 175° C. and cooled, when it is ready for use again. Two hundred and forty kilograms calcium chloride spread 24 cm. deep to a square metre are able to dry 300 cubm. air for four hours, whereby 15 grammes moisture per cubic foot were absorbed. Three units are necessary—one in service, the contents of another being regenerated, and the third in cooling.

Asbestos Cement Boards. K. A. WENIGER. (*Papierfabrikant*, x, 247.)—Sheets that are useful as a substitute for slate, etc., are composed of asbestos and cement. They are manufactured on paper-making machinery similar to that used for book-binders' boards. A cylinder machine, having two cylinders, 860 mm. in diameter and 1,300 mm. wide, can produce 500 to 600 square metres of board 3.5 to 4 mm. thick, in ten hours. The crude asbestos is disintegrated in an edge runner and charged into the beaters together with cement and coloring matter. The cement is ground and sifted through a screen with holes 5 mm. wide and 10 mm. apart before it enters the beating engine. The charge for the beater is 150 kilos of dry asbestos, and it requires 12 to 15 horse-power. The beaten pulp passes into an agitating drum, thence through strainers with slits 0.8 to 1.0 mm. wide to the cylinder board-machine. The cylinders are covered with No. 50 mesh wire gauze, supported by a No. 5 mesh wire; they run at a speed of 20 to 25 m. per minute. The web of stuff is couched in the usual way, passing with the felt over a suction box, and is collected on the press roll with about 55 per cent. of moisture. The couch-rolls have a diameter up to 2,000 mm. and are mounted on oil buffers to absorb the shock when the board is removed. The boards are cut at once to a suitable size, then placed singly between iron plates previously greased with "petroleum and oil," and submitted to heavy pressure in hydraulic presses; in a few hours they have set as hard as stone. The solid matters in the black-waters from the board machine are collected in filters and the moist stuff is returned to the heaters. In certain cases the hardened boards must be steeped for a long time in running water to remove crystallizable salts.

Alloys and Electrolytic Deposit of Radium. F. DE MARE and C. JACOBS. (*Bull. Acad. roz. Belge*, 1912, 53.)—By the reduction of a mixture of silver chloride and radium sulphate with calcium carbonate and charcoal in a gas-furnace a radium-silver alloy was produced. It was radio-active, of a yellow color, showed a gray fracture, and could, with care, be drawn to a thin wire. By electrolysis of a solution of radium acetate between platinum electrodes, a coherent, brown, very active deposit was obtained on the cathode. It is stated that at a definite thickness quartz allows the passage of the light rays emitted by a radium salt, whilst absorbing the α, β, and γ rays.

How and When Diamonds were Made by Nature. R. B. CROCKER. (*Chem. News*, civ, 248.)—Facts are given from which the theory is deduced that diamonds were formed before organic matter, when the earth's atmosphere consisted mostly of CO and CO_2, and the metallic elements were in the molten state. Molten iron, solidifying in fissures and cavities filled with CO and CO_2, imprisoned them, and, under the enormous pressure due to cooling and contracting the oxygen united with the iron and the carbon crystallized as diamond.

Tungsten Carbide for Meter Jewels. ANON. (*Brass World*, viii, 5, 177.)—It is claimed that tungsten carbide is sufficiently hard for use as meter jewels. A bead of metallic tungsten is obtained by fusing the powdered metal in an electric furnace. These beads are then heated in a carbon tube furnace of the electric resistance type. The carbon vapors are absorbed by the tungsten and a very hard tungsten carbide is formed. The carbon lowers the melting point of the tungsten so that it fuses, and when it cools there is a depression in the top of the bead, which renders the subsequent drilling and polishing as a meter jewel less difficult.

Cerium-Aluminum Alloys. R. VOGEL. (*Zeit. Anorg. Chemie*, lxxv, 41.)—The alloys of cerium and aluminum were submitted to a combined thermal and microscopical examination, and an equilibrium diagram of the system is given. The metals combine to form the compounds Ce_3Al, Ce_2Al, $CeAl$, $CeAl_2$ and $CeAl_4$, the last undergoes transformation at 1005° C., the β form passing on cooling, with a contraction in volume, into the more stable α form. The alloys, unlike those of cerium with lead and tin, are almost unaffected by air or water, only those containing less than 25 atoms per cent. of aluminum being very slowly attacked. The compound $CeAl_2$ is not appreciably affected by strong hydrochloric, nitric or sulphuric acid, and the alloys generally are less readily attacked by acids than the constituent metals. They may be burnt in the Bunsen flame, but only those rich in cerium are pyrophoric. The maximum hardness about 6 on Mohs' scale, is shown by the compound $CeAl_2$, which is very brittle and has a melting point 600° C. above that of cerium and 800° C. above aluminum.

Solution of Copper in Water. J. PIONCHON. (*Compt. Rend.*, cliv, 865.)—A cell formed of two plates of copper with water as an electrolyte shows a momentary current when one of the plates is lightly tapped, the tapped electrode becoming negative. If the water is in contact with the copper plates for some time, this effect disappears, but it may be renewed by changing the water. This behavior is supposedly due to the solution of minute traces of copper

by the water, in too small a quantity to be detected chemically; but the water rendered inactive becomes active again after shaking with iron. It is claimed that by this method it can be stated whether water has been in contact with copper, when no trace can be detected by ordinary methods.

Vapor Pressures of Alkali Metals. L. HACKSPILL. (*Comptes Rend.*, cliv, 877.)—The vapor pressures, between 250° C. and 400° C., were measured by sealing the metal in a U-tube, one limb of which was kept at the required temperature, and the other just above the melting point of the metal. From the observed changes of level of the metal in the two arms of the tube, together with the density at the melting point, and coefficient of expansion of the liquid metal, the vapor pressure can be calculated. Figures and curves are given for cœsium, rubidium, potassium, and sodium. The highest vapor pressures measured were:— cœsium, 15.88 mm. at 397° C.; rubidium, 6.14 mm. at 367° C.; potassium, 4.61 mm. at 400° C.; and sodium, 0.26 mm. at 397° C.

Preservation of Wood with Fluorides. R. NOWOTNY. (*Oester. Chem. Zeit.*, xv, 100.)—To increase the preservative effect of sodium fluoride on wood, it is mixed with nitrophenols; one of these mixtures, Bellit, consists of 90 parts of 90 to 95 per cent. sodium fluoride and 10 parts of dinitro phenolanilin. This compound is active as an antiseptic; but does not, like free dinitrophenol, act upon the iron vessels in which the timber is impregnated. The selective phenomena observed when treating timber with mixtures of zinc fluoride and hydrochloric acid are reproduced in the Bellit treatment. Impregnation by steeping results in the solution being absorbed as a whole, but in the hydrostatic and pneumatic pressure methods the nitro-compound is absorbed more rapidly than the fluoride. Examination of telegraph poles, which had been treated in 1905 and 1906, with copper sulphate and zinc fluoride respectively, has shown that in general the latter is much the better preservative.

"Sickness" of Aluminum. ROBT. GRIMSHAW. (*Metal Ind.*, x, v, 194.)—Tin, when subjected to severe cold, is subject to a disease known as the "tin-pest," and it has lately been discovered that aluminum is subject to a similar disease, which decomposes it. The first to mention this was Ducru, head chemist of the technical section of the French Artillery. Prof. Heyn then took the matter into consideration, together with Prof. Bauer, in the laboratory of Gross-Lichterfelde near Berlin. The hypothesis they offer in explanation is that in the rolling process two neighboring strips of the sheet metal attain different degrees of electrical tension, and when they come in contact with a solution of a salt, act as two different metals in electrolysis; the hardest worked strip playing

the part of the positive electrode and being decomposed. As a preventive it is recommended to heat the metal to 450° C. or 842° F. There is, however, reason to fear that such a temperature would make the articles soft and less durable.

Artificial Pumice Stone. ANON. (*Amer. Mach.*, xxxvi, 15, 590.)—Natural pumice is so common to volcanic eruptions that with such outbursts the surface of the adjacent sea is covered with the floating stones. The material is a kind of obsidian which has been rendered porous, while in a molten state, by the expansion of gas or steam in its substance. Pumice is not always reliable, for it will vary in grain and hardness, sometimes in the same piece. An artificial pumice is now being made at Bietigheim in the valley of the Enz. Its constituents are sandstone and clay, and ten different grades are manufactured. There is a hard and a soft kind designed for leather, felt and wood industries; another kind for stucco workers and sculptors; a soft finely grained variety for polishing woods and tin goods; another for lithographic stones; while other varieties are prepared suitable for various duties.

Solid Oxygen by Evaporation of the Liquid. J. DEWAR. (*Roy. Soc. Proc. Ser. A.*, lxxxv, 589.)—It is more difficult to solidify oxygen than hydrogen or nitrogen, because oxygen has a small vapor pressure at its melting point. With the aid of cocoanut charcoal (75 gm.), as much as 10 c.c. of liquid oxygen have been changed to a transparent jelly within a silvered, vacuum jacketed tube placed inside a wider tube filled with liquid air. The pressure required for solidification was determined by a McLeod gauge at 1.12 mm.; the melting point would be 53.3° K. by extrapolation from Willard Gibbs's vapor tension formula. A subsequent determination by a hydrogen thermometer gave 54° K., while Kamerlingh Onnes finds 54.6°.

New Hard Fired Porcelain Colors. W. PUKALL. (*Sprechsaal*, xlv, 211.)—New colors are obtained by allowing suitable refractory, porous, colorless bodies, such as aluminum hydroxide, silicic acid, Zettlitz kaolin, zinc oxide or a mixture of zinc oxide with aluminum hydroxide in the ratio of 1 ZnO, 2 Al_2O_3, meta-stannic acid, calcium phosphate, etc., to absorb easily soluble metallic salts which yield coloring oxides, and then calcining at Seger cone 7, whereby the salts are decomposed. Cobalt oxide with alumina, or with alumina and zinc oxide, or with silicic acid as the basis, gave tones ranging from the most delicate ultramarine to the deepest dark blue, suitable for porcelain and earthenware. Chromium oxide in very small amounts, with an alumina basis, gives reddish gray tones, especially under a glaze rich in magnesia. With the alumina-zinc oxide basis, 0.2 molecule of chromium to 0.5 ZnO, Al_2O_3 gives bright pink colors, which beyond that amount turn to reddish-gray. By saturat-

ing AlOH with manganese nitrate so as to produce on ignition a body with the composition Al_2O_3, 0.15, to MnO, 0.2, a violet red, is obtained which is changed to brown by larger amounts of MnO. Colors with 0.1 to 0.3 molecules of Fe_2O_3 to 1 molecule of alumina, stand fairly well under stoneware glazes, though somewhat brownish-red in appearance. Serviceable, red under-glaze stoneware colors are given by mixtures of 0.2 to 0.8 molecules of ferric oxide to 1 molecule of calcium phosphate as the basis. Copper red under-glaze colors can be produced by copper nitrate with alumina or with silicic acid as the basis, though the latter gives a brighter and more reliable effect. With 1 molecule of silica a bright red is produced with only 0.4 molecule of cupric oxide. Bright to dark brown colors are produced on porcelain from uranium nitrate, with 0.2 to 1.0 molecule of uranium trioxide to 1 molecule of alumina, silicic acid, or Zettlitz kaolin. Under an alkali glaze upon stoneware very bright orange yellows are obtained.

Moisture in Coal. E. H. ARCHIBALD and J. N. LAWRENCE. (*J. Ind. Eng. Chem.*, iv, 258.)—Experiments on the drying of bituminous and anthracite coal under different conditions are described which show that the U. S. A. official method (heating for 1 hour at 104°–107° C.) gives figures for moisture, which are much below the true value; the error in the case of some bituminous coals amounting to 40 per cent. of the true content of moisture. The errors, probably mainly due to the oxidation of iron, or sulphur, or both, and to the incomplete expulsion of moisture, are much greater for bituminous coal than for anthracite. For determining moisture in bituminous coal, it is recommended that the coal be heated in a current of dry air at a temperature not below 110° C. and the moisture expelled be absorbed by anhydrous calcium chloride.

Influence of Silicon on the Properties of Iron. P. PAGLIANTI. (*Metallurgie*, ix, 217.)—A series of iron-silicon alloys was produced containing from 0.24 to 5.26 per cent. of silicon; 0.12 to 0.15 of carbon, 0.23 to 0.60 of manganese, 0.4 to 0.64 of sulphur, and 0.31 to 0.45 per cent. of phosphorus. They were examined in the cast, annealed and quenched conditions as to their fracture, tenacity, elongation, contraction of area, hardness, resistance to bending, specific gravity, electrical conductivity, and magnetic permeability, and the results are tabulated and illustrated by curves. The conclusions are:—(1) Silicon raises the yield point and increases the hardness and tenacity, while it diminishes the elongation and contraction in area of untreated, annealed and quenched alloys. (2) The resistance to bending (of notched bars) is changed very little up to 1.40 per cent. of silicon, and is diminished when the silicon content exceeds 1.60 per cent.; annealing and chilling increase the brittleness, (3) the specific gravity diminishes as silicon

increases, (4) electrical resistance rises with increasing silicon, (5) the addition of silicon to iron improves it magnetically by increasing the permeability and decreasing the hysteresis, 2 per cent. of silicon gives good results. The best magnetic results were obtained by annealing a 2 per cent. silicon alloy. The paper is illustrated by 10 microphotographs, and there is a summary of previous work.

Use of Coke-Oven Gas for Cities in Germany. G. S. COOPER. (*J. Gas-Lighting*, cxviii, 107.)—The towns of Waldenburg, Altwasser, and Salzbrun in Silesia, Essen, Dortmund and Mülheim have, for some time, been supplied with gas from neighboring coke oven plants. The entire supply of Mülheim-on-the-Ruhe and of Barmen, about 40 miles distant, is obtained from two coke oven plants. The installation consists of 50 Koppers' horizontal regenerator ovens, each capable of taking from 8 to 10 tons for a charge, the time of carbonization is 24 hours and only the richer portion of the gas—that evolved from the second to the twelfth hour, which is about 50 per cent. of the yield—is used for distribution. During this period one oven will produce 70,600 cubic feet of gas of a calorific value well over 600 B.t.u.'s per cubic foot with the average composition—CO_2 1.2, CO 6.8, H 49.5, CH_4 38.3, and N 4.2 per cent. A yield of 65 to 69 per cent. of large coke, 5 to 6 per cent. of tar, and 1.3 to 1.5 per cent. of ammonium sulphate is obtained. The gas costs 17 cents per 1000 cubic feet, and is sold for 70 cents per 1000 cubic feet.

The Purity of Aluminum. ROBT. GRIMSHAW. (*Metal Industry*, x, 6, 238.)—The aluminum in the market is generally impure, most of it contains silicon and iron. Mierzinski states that the presence of foreign metals makes aluminum hard and brittle; 5 per cent. of iron or copper renders it almost unworkable; 10 per cent. of copper makes it as brittle as glass, and it blackens in the air. It remains perfectly workable with 50 per cent. of silver and takes a beautiful polish. With 10 per cent. of gold its malleability remains unchanged, and its hardness is increased. If 0.1 per cent. of bismuth is added to it, the aluminum becomes so brittle that it is unworkable even after annealing.

Potash from Alunite. ANON. (*Oil, Paint, and Drug Reporter*, April 22, 1912.)—As continued interest is displayed in many places in the prospective discovery of potash in the United States, the Geological Survey has reissued a report made by Hoyt S. Gale on alunite, a potash bearing mineral, found in a newly discovered deposit near Marysvale, Utah. This alunite is of special interest as the potash it contains is believed to be commercially soluble, that is, it can be obtained as a fertilizing material by simple roasting and leaching of the rock. The bulletin describes a vein believed to be of considerable size, which though it can not supply the whole

American demand, may meet local needs. The commercial development of this deposit will be of the greatest importance in stimulating exploration for other similar deposits. Alunite has been observed by other members of the Geological Survey at several points in many Western States, and it may be expected that further prospecting and investigation will disclose deposits that may yield a large tonnage.

Iron Ore Deposits in Norway. ANON. (*Engineering*, xciii, No. 2415, 481.)—The South Varanger iron ore deposits are being actively worked and important extensions have been made. They supply a practically new product, a concentrated iron ore, termed "Slig" to the international market. The iron ore is got by quarrying, rather than by mining methods; and the blasting operations are on an unprecedentedly large scale. The area blasted on one occasion was between 60 and 70 metres long, one end 10 m. wide and the other 20 m. wide, and 11,000 cubic metres of iron ore were displaced, or about 38,500 tons. The export quay is built of concrete blocks with two electric cranes of a capacity of 150 tons per hour. The coal discharging quay is 50 m. long with a crane that can discharge 800 tons per day.

Condensite. ANON. (*Elect. Rev. and West Electri.*, lx, 199.)—This is a new insulating material, produced by J. W. Aylesworth, by the action of phenol on formaldehyde. It resembles gum, is transparent, hard, insoluble in alcohol and of high dielectric strength, and does not fuse or soften when heated. In solution it can be used as an air-drying varnish, oven-drying enamel, or as a cement. It can be adapted for impregnating electrical apparatus or for moulding. It is said to be uninflammable, non-hygroscopic and an insulator for heat as well as electricity. Its tensile strength is about 4,000 lbs. per square inch with a compressive strength of 22,000 lbs. per square inch when cold, and 11,000 lbs. when hot.

Manufacture of Balloon Fabrics. CHURREL. (*Gummi-Zeit.*, xxvi, 894, 938, 972, 1016 and 1055.)—Fabrics should be of the best quality, preferably Egyptian Sea Island cotton. The fabric should be freed from sizing materials by sufficient washing; it should give practically no starch reaction with a potassium iodide solution of iodine. Mechanical tests should be made on samples which are neither quite dry nor too wet. Fine, hard Para rubber should be used for coating, though it may be replaced by Peruvian Ball or smoked plantation sheet rubber up to 40 per cent. if the vulcanization is carefully done. Soft Para or Peruvian Tails or deresinified Guayule are unsuitable, as the rubber on the fabric resinifies with time. Good mixings are: (1) To secure impermeability by gas: 400 parts of hard fine Para rubber, 3 of paraffin (melting point about 66° C.), 40 of sulphur, and 17 of magnesium

oxide; (2) to raise the tensile strength of the fabric: hard fine Para rubber, 400; paraffin (m. pt. about 66° C.), 4; magnesium carbonate, 260; magnesium oxide, 36; and fine sulphur, 40 parts. All powders should be sifted twice; (3) to obtain impermeability to gas in cold-cured fabrics: fine hard Para, 400; paraffin (m. pt. about 66° C.), 5 parts. Benzine and benzol, free from water or suspended iron-oxide, are suitable solvents. The boiling point should be between 70° and 100° C., and not more than 8 per cent. should boil over 100° C. The rubbered fabrics are prepared and combined on a smooth calender. Vulcanization is done on drums by steam, or if sensitive colors or fabrics are used, by hot air under pressure. The fabrics must be protected from direct access of steam, 50 to 90 minutes cure at not exceeding 133° C. and 2.2 atmospheres is suitable. With hot air 1 to 2½ hours at not more than 129° to 130° C. at 4 to 6 atmospheres is suitable. It is best to aim at a slight undercure to allow for after-vulcanization.

"Sulphinol." A New Photographic Developer. J. DESALME. (*Bull. Soc. Franc. Phot.*, iii, 94.)—The most efficient photographic developer of the hydroxydiphenylamine derivatives is *p* amino-*p'*-hydroxydiphenylamine-*o*-sulphonic acid known as "Sulphinol." It is slightly soluble in water, but readily soluble in alkalies and alkaline carbonates. It gives soft images of good gradation with pure whites; under normal conditions the image appears in about 3 minutes and development is complete at the end of 7 or 8 minutes. The developer is very sensitive to bromide. A developing bath for papers may consist of sulphinol, 10 to 15 grammes; crystallized sodium sulphite, 40 to 50 Gm.; "dry" sodium carbonate, 20 to 30 Gm.; water, 1000 c.c. Satisfactory results are obtained in developing negatives by using sulphinol and quinol, *e.g.*, sulphinol, 10 Gm.; quinol, 5 Gm.; sodium sulphite, 50 Gm.; sodium carbonate, 50 Gm.; water, 1000 c.c. The developing solutions are stable.

Propagation of Warm Waves in European and Asiatic Russia. H. v. FICKER. (*Akad. Wiss. Wien. Ber.*, cxx, 2a, 745.)—The lines which connect spots of simultaneous rises of temperature, are, on the whole, meridional, but may be strongly curved, and warm and cold currents may then proceed on parallel paths. The general drift of the currents is eastward. Most warm waves are preceded and followed by cold waves. Islands or tongues extend into the cold areas from the warm areas. The winds bringing warm weather mostly blow from the southwest fairly in the direction of the warm wave, while the cold waves come at right angles to it. The temperature maxima with warm waves differ much less from one another than with cold waves. Sometimes a warm wave may be traced from the Atlantic and Arctic shores right over to Eastern Siberia; but they generally vanish before

they cross Lake Baikal. The rate of propagation is about 33 Km. per hour, about the same as cold waves, and the two kinds of waves are probably interconnected. The humidity observations suggest that the warm waves arise in the ocean. The abnormal heating of continental areas is confined to shallow surface strata as a rule. Warm waves develop mostly in the front of a depression, and cold waves in the rear of the depression, the centre of which generally lies near the polar boundary of the warm area; these depressions consist of two neighboring currents of different temperatures. It appears, in general, that the warm southwesterly winds are always blowing as part of the general circulation, and that they are temporarily lifted from the surface and pressed upward by the invasion of cold waves, which also belong to the general circulation. The phenomena are simpler in Russia than elsewhere because the temperature variations are more pronounced there, though caused by abnormal temperatures in relatively shallow strata.

The Effect of Steam on Portland Cement.—The Bureau of Standards, of the Department of Commerce and Labor, in connection with the investigation of structural materials is conducting a series of tests to determine the action of high-pressure steam on Portland cement. It has been found that high-pressure steam will greatly accelerate the hardening of certain cements, increasing their strength several hundred per cent., but will cause the complete disintegration of other cements which under normal conditions appear to have the usual physical qualities. The present investigation is in part an extension of the work reported in Technologic Paper No. 5, "The Effect of High-Pressure Steam on the Crushing Strength of Portland Cement Mortar and Concrete." The equipment for this purpose consists of a small steam-pressure tank, or so-called "autoclave," suitable for pressures up to 50 atmospheres (515 pounds per square inch); and a large cylindrical steel tank, 12 inches by 5 feet inside dimensions, suitable for working pressures up to 70 atmospheres (1,030 pounds per square inch).

It has been proposed that specifications for the purchase of Portland cement be amended to include a test of exposing cement to a steam pressure of 20 atmospheres (294 pounds per square inch) for a period of two hours. It is required that the cement remain sound and that the tension briquettes show a given increase in strength.

It has been found that certain cements which meet the steam test of 212° F. for five hours, as required by present specifications, fail under the proposed high-pressure steam test. In investigating the cause and interpretation of this failure, practically all brands of cement purchased by the Government are being subjected to the high-pressure steam test in connection with the regular routine

specification test, and much valuable information is being accumulated.

Tests are also being made on specially prepared cements of various degrees of fineness and after seasoning for different periods. Other series of tests are being made in exposing cements neat, and in mortars and concretes to a series of pressures ranging up to 1,000 pounds per square inch and for various durations. Tensile and compressive strength, linear expansion and contraction, water absorption, and other physical properties are being determined. The effect of temperature, pressure, and moisture content of the atmosphere, or degree of water saturation, is being studied independently.

Some interesting results are also being obtained by subjecting to high-pressure steam pieces of mortar and concrete from sound and disintegrated structures which have been in place for several years.

To determine the value of the high-pressure steam test as a determination of the soundness and structural quality of Portland cements, a large number of concrete cylinders, 8 inches in diameter by 16 inches in length, are being made of cement which fails to meet the normal 212° F. steam test, as well as of cement which passes this test but fails to meet the proposed 20 atmosphere steam-pressure test, and of cement which meets both of the above requirements. The cements are being tested in a normal 1:2:4 proportion concrete mixture, and will be exposed in various localities over a period of years and tested for elastic properties and compressive strength.

Photographic Intensification. J. DESALME. (*Bull. Soc. Franc. Phot.*, iii, 96.)—After many trials it has been found that sodium stannite reduces silver chloride most energetically, and produces the most intense silver image. In intensifying by this method the image is converted into silver chloride by means of a 2 to 3 per cent. solution of cupric chloride, slightly acidified with hydrochloric acid. The bleached image is washed and redeveloped in a sodium stannite solution prepared by adding 18 c.c. of NaOH (40° Be.) to 10 Gm. of stannous chloride dissolved in 100 c.c. of water, and diluted to 250 c.c. To obtain warm brown tones the bleached image is treated with a 5 per cent. solution of Na OH before redevelopment. The process is equally applicable to negative or positive silver images.

Carbon Monoxide in Illuminating Gas. ANON. (*Circular of Bureau of Standards*, No. 32, 1912.)—Existing legislation shows no tendency to limit the carbon monoxide content of gas, although it is the only constituent of illuminating gas which, in the amounts ordinarily found, is poisonous. Coal gas contains from 5 to 10 per cent. of carbon monoxide; water gas from 25 to 30 per cent.

To limit the amount of carbon monoxide in the gas sold might limit the amount of water gas made. Such regulations as would prevent the operation of water-gas plants now in existence would be very severe, but the extension of present plants should not be directed toward increasing the use of coal gas rather than of water gas. The use of water gas may possibly not be much more dangerous than coal gas. A large proportion of the cases of death or illness by gas poisoning are suicidal; and the character of the gas would have only a small influence upon the result. A large number of deaths and cases of poisoning called "gas poisoning" are due not to the gas itself but to the carbon monoxide formed by combustion of the gas with insufficient supply of air, due to faulty appliances. It is possible that the protection of the public from danger will be found rather by regulation of appliance, and the general education of gas-users as to proper precautions, than in the limitation of the carbon monoxide content of the gas itself.

Foreign Markets for Motor Vehicles.—As well as supplying the great home demand for motor vehicles, the automobile manufacturers of the United States are annually making great strides in their invasion of the foreign markets, according to a monograph entitled, "Foreign Markets for Motor Vehicles," recently issued by the Bureau of Manufactures, Department of Commerce and Labor. This publication is a compilation of reports from American consuls stationed in every part of the globe, and is arranged with the particular end in view of aiding American manufacturers to extend their foreign sales. It describes the peculiarities of the various markets, special local conditions and prejudices to be considered, foreign competition to be met, and the best methods of selling cars.

Canada is the United States' best market, the majority of the cars in use in that country being either made entirely in the United States, assembled in Canada from parts imported from the United States, or made by Canadian branches or affiliations of American firms. The exports of automobiles from this country to Canada have risen from 1,230 in 1909 to 4,687 in 1911.

The high road-clearance, flexibility, and moderate price of the American car are steadily winning it favor in regions where highway conditions are similar to those in the United States. The market in Australia and New Zealand is already being well cultivated by American exporters, while Argentina, Brazil, and Uruguay, in South America, and British South Africa are named as promising fields for future sales. It is estimated, also, that there are more American than European cars in use in Mexico.

In the Far East, Ceylon, India, Japan, Siam, and the Straits Settlements are the most likely markets. China has little use for automobiles, as most of the roads of that country do not permit their use. In the Straits Settlements the principal buyers are

wealthy Chinese, who demand comfort and luxury in their cars rather than high power. As a result, low-hung, smooth-running cars are the most popular, and the local trade often demands that each car be fitted in accordance with the individual taste of the owner. Right-hand drive is essential here, as in the Orient all traffic turns to the left, instead of to the right, as in the United States.

The United Kingdom has been, and continues to be, an excellent market for American cars, ranking next to Canada in purchases from the United States, but the sales in Continental Europe have thus far not been extensive. The excellent roads of most of the European countries permit the use of a heavier, lower-hung car than is found commonly in the United States. In England, however, the low prices and complete equipment of American cars are fast increasing their popularity, while they are rapidly overcoming the prejudice against them, caused by doubt as to their durability, due to the sale of many cheap, unsubstantial American-made bicycles in England some years ago. The method of American dealers of putting their cars on the market fully equipped is in strong contrast with the practice of Continental makers, who quote prices on the chassis only, with the body and all equipment listed as extras.

Action of Acids on Concrete. E. NEUMANN. (*Tonind. Zeit.*, xxxvi, 601.)—Concrete drains have suffered more or less damage, some of them in comparatively short periods. from the time of their construction. In every case the destructive action was traced to the presence of acid in the water which reached the drains either internally or externally. In one case the swampy soil surrounding the drain contained iron pyrites, and the water became charged with sulphuric acid; in the other cases the air in the drains was heavily laden with hydrogen sulphide, which slowly oxidized to sulphur and sulphuric acid. Other mineral and organic acids, such as hydrochloric, oleic, acetic acids and carbon dioxide were found almost as noxious. It is concluded that the destructive action of acids is due to two causes, viz:—(1) The formation of certain calcium and aluminum compounds, especially calcium sulphate, which is accompanied by a large increase in volume; (2) the formation of soluble compounds, especially calcium bicarbonate, which dissolve and cause the concrete to collapse. The chief remedies proposed are:—To provide adequate ventilation inside the drains; to use dense, non-porous clinker, poor in lime, as basis for the concrete; and to cover the exposed surfaces of the concrete with a coat of tar, or, best of all, to protect the foundations of the drains with tar-felt or asphalt.

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